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REPORTS

FROM

COMMISSIONERS, INSPECTORS,

AND OTHERS:

TWENTY-SEVEN VOLUMES.

—*(24.)*—

RIVER CLYDE PURIFICATION; SEWAGE DISPOSAL; PUBLIC HEALTH.

Session

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COMMISSIONERS, INSPECTORS,

AND OTHERS:

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TWENTY-SEVEN VOLUMES:—CONTENTS OF THE

TWENTY-FOURTH VOLUME.

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REPORT

OF

SIR JOHN HAWKSHAW,

THE COMMISSIONER

APPOINTED TO INQUIRE AS TO

THE PURIFICATION OF THE RIVER CLYDE.

TOGETHER WITH

APPENDIX AND MINUTES OF EVIDENCE.

Presented by Command of Her Majesty to both Houses of Parliament.

EDINBURGH: PRINTED BY MURRAY AND GIBB,
FOR HER MAJESTY'S STATIONERY OFFICE.

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COMMISSION.

VICTORIA R.—Victoria, by the Grace of God of the United Kingdom of Great Britain and Ireland, Queen, Defender of the Faith, to Our trusty and well-beloved Sir John Hawkshaw, Knight, one of the Honorary Councillors of the Institution of Civil Engineers, Greeting.

Whereas, We have deemed it expedient, for divers good causes and considerations, that a Commission should forthwith issue for the purpose of inquiring as to what towns and places contribute to the pollution of the River Clyde and its tributaries; and how and by what means the sewage of such towns and places, and the refuse arising from industrial processes and manufactures carried on within the same, can be utilized or got rid of without risk to the public health, or serious injury to such processes and manufactures, otherwise than by discharge into the River Clyde and its tributaries, or rendered harmless before reaching them; and also for the purpose of inquiring into the best means of otherwise securing the purification of the said River and its tributaries, and of remedying any evils or inconveniences arising from its present polluted state:

Now know ye, that We, reposing great confidence in your zeal, ability, and discretion, have authorized and appointed, and do by these presents authorize and appoint, you, the said Sir John Hawkshaw, to be Our Commissioner for the purposes aforesaid.

And for the better enabling you to form a sound judgment in the premises, We do hereby authorize you to call before you all such persons as you may judge most competent, by reason of their situation, knowledge, and experience, to afford you correct information on the subject of this inquiry. And We do further hereby authorize you to employ such persons of scientific knowledge as you may consider best qualified to aid and advise you, and to adopt all other lawful ways and means to effect the object of this inquiry.

And it is Our further will and pleasure that, so soon as the same can conveniently be done (using all diligence), you do report to us in writing, under your hand and seal, your several proceedings by virtue of this Our Commission, together with your opinion on the several matters herein submitted for your consideration, and all questions therewith connected.

And We will and command that this Our Commission shall continue in full force and virtue, and that you, Our Commissioner, may from time to time proceed in the execution thereof, although the same be not continued from time to time by adjournment.

And for your assistance in the due execution of this Our Commission, We have made choice of our trusty and well-beloved James Badenach Nicolson, Esquire, to be secretary to this Our Commission, and to attend you, whose services and assistance We require you to use from time to time as occasion may require.

Given at our Court at Saint James', the Fifteenth Day of December 1874, in the Thirty-eighth Year of Our Reign.

By Her Majesty's Command.

(Signed) RICH'D. ASSHETON CROSS.

RIVER CLYDE PURIFICATION.

REPORT.

MAY IT PLEASE YOUR MAJESTY,—

IN obedience to the commands contained in your Royal Commission to inquire into the causes which have led to the pollution of the river Clyde and its tributaries, and to ascertain the best remedies for restoring the river and its tributaries, as far as may be practicable, to their original pure state, I humbly beg to report as follows:—

The polluted state of the river Clyde and some of its tributaries has for a long time been a source of nuisance to the city of Glasgow and other towns and places, and to the traffic on the Clyde; and the Corporation of Glasgow have for many years had under consideration what means could be taken to remedy it, and they have received many able reports on the subject. I have been furnished with copies of these, of which the following are the principal, viz.:—

Report on the Means of Deodorizing the Sewage of Glasgow, by Thomas Anderson, M.D., F.R.S.E., and J. F. Bateman, C.E. July 1858.

Report on the Sewerage of Glasgow, by J. F. Bateman. December 1858.

Report by Messrs. Bateman and Bazalgette on the Sewerage of Glasgow. 1868.

Report by Professor Anderson in relation to the Sewage of Glasgow. October 1869.

Report, Designs, and Estimate for the Drainage of the Sewage out of Glasgow and the Purification of the River Clyde, by George Thornton, C.E. 1869.

The foregoing reports had relation to the pollution proceeding from Glasgow and the immediate neighbourhood, and did not attempt to deal with that proceeding from the various manufacturing centres and works throughout the region of the Clyde. The scope of the inquiry delegated to me is much more extensive, embracing not only the Clyde, but its tributaries, so far as they are at present suffering from pollution. I have also availed myself of the reports of the Commissioners appointed to inquire into the pollution of rivers, and of the Commissioners appointed to inquire into the best mode of utilizing the sewage of towns, and of numerous pamphlets and statements bearing on the subject. In some cases I have been furnished with copies of these documents by the authors themselves; in other cases by the Town Council of Glasgow, who have throughout this investigation been most ready and anxious to furnish me with the fullest information.

In the Fourth Report of your Majesty's Commissioners appointed to inquire as to the Pollution of Rivers throughout the kingdom, which deals with the rivers of Scotland, much valuable information is given respecting the condition of the river Clyde and its tributaries, and the various pollutions arising from works situated in the valley of the Clyde. I have given this Report the careful study which it merits.

Every facility has been afforded by the various local authorities in the towns and villages embraced in my inquiry, who have readily given all the information I asked for; and I have found manufacturers throughout the district, who are necessarily specially interested in the question, most willing to give information as to the nature of their works and the various processes of manufacture carried on in them.

In order to give the local authorities of the various towns an opportunity of stating

their views as to the best method of remedying the polluted state of the streams and rivers, circulars were issued to them, asking them to attend before me in Glasgow on January 27, 1875. With some exceptions, delegates from the various towns attended. I likewise announced by public advertisement that I would sit at the City Chambers in Glasgow, on Monday, the 17th May 1875, and following days, to hear evidence and receive any suggestions that might be made on the subject. The information elicited on these and subsequent occasions is given in the Appendix.

DESCRIPTION OF THE CLYDE AND ITS TRIBUTARIES.

That portion of the river Clyde which lies between its source and Greenock is 98 miles in length. The tide flows up it as far as Glasgow. Of the tidal portion of this section of the river, that which lies between Glasgow and Dumbarton is of moderate width, its course being determined by artificial banks. From Dumbarton to Greenock (a distance of 7 miles) the river is more estuarine in character, but extensive banks and shoals appear at low water. These shoals cease opposite Greenock, and just below that town there is an unbroken stretch of river, 3 miles in width at all times of the tide.

After that the Clyde again contracts, and its width diminishes to 1½ miles opposite Gourock. Below Gourock it again widens, and enters the Firth of Clyde.

The area draining into the Clyde above Gourock is 1481 square miles in extent.

Tributaries of the Tidal Portion of the Clyde.

The tidal portion of the Clyde receives four principal tributaries,—the Leven, the Black Cart, the White Cart, and the Kelvin.

THE LEVEN.

The Leven drains an area of 305 square miles, including the drainage area of Loch Lomond, to which it forms the outlet. It enters the Clyde on the right bank at Dumbarton, and is much polluted by dye and other works on its banks. It also receives the drainage and refuse of a population of more than 20,000 persons living in the town of Dumbarton and villages of Bonhill, Renton, Alexandria, and Jamestown.

THE BLACK CART AND THE WHITE CART.

The Black Cart and the White Cart enter the Clyde together on the left bank about 6½ miles below Glasgow Bridge.

The Black Cart drains an area of about 107 square miles. It receives the drainage of Johnstone, with a population of about 8000, and the refuse from mills in that town and neighbourhood, besides pollution from other minor sources.

The White Cart drains an area of 93 square miles, and is the most polluted tributary of the Clyde. It receives the whole of the drainage of the large manufacturing town of Paisley, with a population of upwards of 50,000. Before reaching Paisley, it is much polluted by the manufacturing centres of Busby, Cathcart, Pollokshaws and Neilston, Barrhead and Thornliebank.

THE KELVIN.

The Kelvin flows through part of Glasgow, entering the Clyde on the right bank about 2 miles below Glasgow Bridge. It drains an area of 127 square miles. It receives a portion of the sewage of Glasgow, but, before reaching that city, is much polluted by works and domestic drainage at Milngavie, Kirkintilloch, Kilsyth, and Lennoxtown. It also receives the refuse from isolated mills on its banks.

THE PINKSTON, MOLENDINAR, CAMLACHIE, FINNIESTON, ST. ENOCH'S, AND KINNINGHOUSE BURNS.

Besides the above four tributaries of the tidal portion of the Clyde, there are the Pinkston, Molendinar, Camlachie, Finnieston, St. Enoch's, and Kinninghouse Burns, which flow through the city and suburbs of Glasgow, and which, though small in themselves, are considerable sources of pollution, having been covered in and converted into sewers after they enter the city.

Tributaries of the Clyde between Glasgow and Hamilton.

The principal tributaries of the river Clyde above Glasgow, taking them in order from Glasgow upwards, are—

THE ROTTEN CALDER.

The Rotten Calder enters the Clyde on the left bank, 9 miles above Glasgow Bridge, and drains an area of about 22 square miles. There are no works or manufactories or centres of population within the area drained by this stream, and it is not appreciably polluted.

THE NORTH CALDER.

The North Calder joins the Clyde on the right bank, about half a mile above the point where the Rotten Calder enters that river. Its length from where it leaves the Hillend reservoir is 15 miles, and it drains an area of about 50 square miles. It receives the whole of the drainage of Coatbridge and Airdrie, with that of the villages and works which adjoin those towns. Throughout much of its course it is no better than an open sewer.

THE SOUTH CALDER.

The South Calder enters the Clyde on the right bank, about $5\frac{1}{2}$ miles above the North Calder, and drains an area of about 39 square miles. It receives the drainage of some of the villages which supply labour to the numerous ironworks and coalpits in the district through which it flows; but the pollution is not in proportion to the population, which is scattered through small villages, at present mostly undrained.

THE CADZOW BURN.

The Cadzow Burn is insignificant in itself, but is greatly polluted. It serves as a main sewer to the town of Hamilton, through which it flows, and conveys the drainage of a large part of the population of that town, amounting at present to about 12,000 inhabitants, but which will be greatly augmented in the course of a few years from the extension of mining industries in the neighbourhood.

The Clyde above Hamilton.

Above Hamilton, the Clyde is not appreciably polluted, nor are its tributaries. At the same time, it receives, with a few notable exceptions, the drainage of all the towns and villages which lie within its watershed. But as there are scarcely any works and no large centres of population, Lanark, with between five and six thousand inhabitants, being the most considerable, the proportion of polluted liquids which find their way into the river is small as compared with the volume of pure water in it.

I have thus briefly described the tributaries of the Clyde which are chiefly instrumental in polluting it. The accompanying maps will help to convey a better idea of the principal sources of pollution. Plan No. 2 shows the public manufactories in the valley of the Clyde, and the chief centres of population.

Principal Towns on the Clyde and its Tributaries.

The following is a list of towns and villages within the area drained by the river Clyde and its tributaries which at the last census had a population of about 1000 persons and upwards:—

	Population, Census of 1871.
Gourock,	2,940
Greenock,	57,821
Port Glasgow,	10,823
Helensburgh,	8,975
Glasgow, including—	
Partick,	
Hillhead,	
Springburn,	
Govan,	
Kinning Park,	
Crosshill,	
Pollokshields,	569,375
Strathbungo,	
Mount Florida,	
Crossmyloof,	
Shawlands,	
Pollokshaws, and	
Rutherglen,	
Old Kilpatrick,	903
Duntocher and Faifley,	1,921
Renfrew,	4,163
Shettleston,	2,418
Tollcross,	2,819
Cambuslang,	2,218
Uddingston,	1,997
Bothwell,	1,209
Blantyre Works,	1,304
Hamilton,	11,498
Carluke,	3,423
Overton,	1,517
Lanark,	5,099
Kirkfield Bank,	963

The above towns and villages drain either directly into the Clyde or into small streams which flow into it, with the exception of Glasgow and its suburbs, which in part drain also into the Kelvin and the White Cart.

The following towns and villages drain into the larger tributaries of the Clyde:—

	Population, Census of 1871.
Drain into the Kelvin—	
Milngavie,	2,044
Lennoxtown,	3,717
Kirkintilloch,	6,139
Kilsyth,	4,895
Maryhill,	5,842
Drain into the North Calder—	
Baillieston,	2,805
Bellshill and Mossend,	2,233
Airdrie, including—	
Rawyards,	
Drumgelloch, and	15,671
Clarkston,	
Coatbridge, including—	
Whifflet and	22,660
Coatdyke,	
Calderbank,	2,176
Calder Ironworks,	1,787
Chapelhall,	1,707
Holytown,	2,197
Newarthill,	1,530
Drain into the South Calder—	
Cambusnethan,	1,795
Craigneuk,	1,377
Carfin,	1,111
Newmains,	2,545
Motherwell,	6,943
Wishaw,	8,812
Dykehead,	985
Drain into the White Cart—	
Barrhead,	6,209
Drain into the White Cart—*continued*—	
Nitshill,	986
Neilston,	1,716
Busby,	1,621
New Cathcart,	933
Crossmyloof,	988
Eaglesham,	1,237
East Kilbride,	1,100
Paisley,	48,257
Thornliebank,	2,123
Drain into the Black Cart—	
Beith,	3,707
Bridge of Weir,	1,315
Elderslie,	1,114
Johnstone,	7,538
Kilbarchan,	2,678
Linwood,	1,250
Drain into the Leven—	
Alexandria,	4,650
Bonhill,	2,510
Dumbarton,	11,423
Renton,	3,087
Jamestown,	1,163
Drain into Douglas Water—	
Larkhall,	4,973
Stonehouse,	2,623
Strathavon,	3,645
Drains into the Nethan—	
Lesmahagow,	1,418
Drains into Elvan Water—	
Leadhills,	1,033

The amount of liquid refuse produced by the above towns and villages is not by any means proportional to the population, but varies with the number and nature of the industries which give employment to the people, with the sanitary system they have adopted, and to some extent with the rainfall.

For example, a mill employing 700 hands may discharge one and a half million gallons of polluting liquid into the public drain or adjoining water-course each day, whilst

the amount that would be discharged into the same channel, arising from the persons employed in the mill, would not exceed 32,000 gallons, or barely a fiftieth of the above quantity, even if the sanitary arrangements of their dwellings were perfect.

The above case is an extreme one, the work I have selected being one of the largest dyeworks in Glasgow,—a class of work in which more water is required than in perhaps any other.

Many of the villages and towns in the above list have no system of drainage, and no water supply. Some of the refuse is thrown into middens or ashpits, from whence it is taken by farmers on to their land. Some, comprising all the household slops, is thrown in front of the door, where the liquid portion soaks into the ground, or, in dry weather, evaporates, and in wet weather is carried, with much of the solid polluting matter, into the nearest water-course, and so to the Clyde.

In determining the best method of dealing with the sewage and manufacturing refuse of the population of so large an area, it will be necessary to take into consideration the vast changes taking place in the district, the extension of mining operations, and of new works and manufactories, and the probable variations in the numbers forming the existing town and village groups. In parts of the district in question, where a large part of the population is employed in mining industries, the numbers are liable to sudden increase or diminution. The population of Hamilton, which now numbers about 12,000, may shortly be increased by 50 per cent. or more, to supply the labour for the coal-pits which are now being sunk. In other parts, as in the neighbourhood of Airdrie, for instance, the population may diminish or remain stationary, as seams of coal are worked out, or it is found that they cannot any longer be profitably worked.

Methods of Disposing of Solid and Liquid Refuse or Sewage.

I believe that there will be little variety of opinion as regards dealing with the solid or dry refuse. The producers of this should find means of disposing of it otherwise than by throwing it into running water, and the practice should in future be prohibited by law.

It may be as well here to describe generally and briefly some of the systems proposed or in use for dealing with liquid refuse or sewage.

These may be classed as follows: viz. Gravitation, Irrigation, Filtration, and Chemical treatment.

GRAVITATION.

The first and most natural is the Gravitation system, which consists in conducting the sewage by pipes or covered conduits to some point, provided such a point can be found, where it may be discharged. It must be borne in mind that this system of gravitation, to a certain extent, is common nearly to all other systems. The sewage must be conducted, either by gravitation or pumping, to some place where it may be dealt with, and in large towns, if it is to be applied to irrigation, it must be led to some distant place. The Liernur system, by the creation of a vacuum, draws sewage from given districts to central depots, where it is proposed to be dried by the application of heat; but that system could only deal with a portion of the polluted liquids of a town; and whether the sewage is ultimately to be used in fertilizing the land, or is to be rendered innocuous by chemical treatment or filtration, up to a certain point it must flow in artificially-constructed channels by gravitation alone, or with the assistance of pumping when the fall is insufficient.

IRRIGATION.

By the Irrigation system is meant the distribution of sewage over the land, whereby, if the soil be of a suitable character, and the area irrigated large enough in proportion to the sewage distributed over it, the liquid flowing from the land is rendered comparatively pure and inoffensive. This system has been tried more or less completely, and with varying success, at Edinburgh, Croydon, Rugby, Carlisle, and many other places.

Where there is soil of a suitable description and land available to which the sewage can be conveyed at a moderate outlay, and so situated as to prevent the sewage farm from becoming a nuisance, it may be employed with advantage. But its application on a large scale is beset with many difficulties. The opposition of surrounding proprietors to the proposal to place vast sewage farms in their neighbourhood would, in many cases, be great and proportionately costly, and in some cases fatal. The cost of distribution of sewage over the land would not increase in direct proportion to the area irrigated, but at a greater rate; nor have we any experience of how far the nuisance of a large area of many thousand acres irrigated with sewage would extend. On these grounds it is not safe to argue, from small irrigation farms to large ones, either from an economical or a sanitary point of view. There may be cases where, on a moderate scale, irrigation may prove a good method, and in some such cases it may be the best.

FILTRATION.

The Filtration system consists in passing the sewage through artificially-constructed filter beds, or through the soil when that is suitable. A fair trial was given during three years to the system of filtration through artificial filters at Rugby, and it resulted in failure. The difficulty of disposing of the solid matters, retained in the form of an offensive sludge by the filters, except on a comparatively small scale, would be great, and it would, I think, be impracticable to deal with a large amount of sewage by this system alone.

CHEMICAL TREATMENT.

Several companies have been formed, and many patents have been taken out of late years, for the deodorization of sewage by chemical treatment, and the preparation of saleable manure from it. Purchasers have not been found for the manures which have been made, though the quantities manufactured hitherto have not been large. In some cases the manures have proved worthless, and have been allowed to accumulate in the neighbourhood of the works. Some of them, no doubt, possess valuable qualities to a limited extent, and as these qualities become better known, purchasers will be more readily found for them. Still, though the cost of treatment of the sewage may be reduced by the sale of the manure, the cost of the substances used for deodorization will probably rise as the demand for them increases. The cost of treatment has in many cases been calculated on the basis that some of these substances would be obtained for nothing, or at nominal rates, as the waste products of manufacturing processes; but they would rapidly become marketable commodities, as in some cases they have already done, even with the small demand which has arisen for them.

By the addition of certain chemical substances in proper proportions, the solid matters in sewage may be precipitated and rendered inoffensive; and if the effluent water be afterwards passed over artificially-constructed filters, or over suitable land so as to oxidize the matters in solution, the effluent water may be rendered tolerably pure. The chief objection to the system at present is its costliness, and that it is still in an experimental state. The Patent Sewage and Manure Company undertook to deal with the sewage of Coventry free of charge; but instead of the profit they anticipated, the cost of treating the sewage, amounting to 2,000,000 gallons a day, is now about £10 a day, exclusive of the interest on the cost of the works and depreciation of plant. Their machinery for making the sludge into manure was not, however, complete when I received this information respecting the cost of their process. The Corporation of Leeds are now dealing with the sewage of that town on a system somewhat similar to that patented by the Native Guano Company. The sewage amounts to about 12,000,000 gallons a day, and on this quantity £15,000 a year is expended at the sewage works on labour, materials, and pumping alone. The cost of the works, including land, was about £48,000. The effluent water at Leeds is not by any means pure, but might be rendered so by a larger expenditure in deodorizing substances and precipitants, and by an outlay on filter beds.

For the effectual chemical treatment of the quantity there dealt with, at least £20,000 a year would be required, as I am informed by Mr. Crookes, F.R.S., the chairman of the Native Guano Company, who takes great interest in these works.

An official trial of the Native Guano Company's process (known as the A B C process) was made at the Crossness outfall of the Metropolitan Drainage Works. In Sir

Joseph Bazalgette's and Mr. Keates' reports on the trial, it was shown that the cost of making a ton of native guano far exceeded the amount which it could reasonably be hoped to realize when offered for sale.

From reports which have been submitted to me on other processes which have any claims to efficiency, I find that in all cases the cost of manufacturing the artificial manure from sewage would greatly exceed the sum which its sale could be expected to produce.

GLASGOW AND ITS NEIGHBOURHOOD.

As will be seen from the accompanying plans, the centres of population and manufactures are very irregularly distributed throughout the region of the Clyde. The principal groups lie in and about the towns of Greenock, Dumbarton, Paisley, Glasgow, Coatbridge, and Hamilton. Hamilton is the least important industrial district at present; but beneath it lie thick seams of coal, which will shortly be worked. Six pits are now being sunk in the immediate neighbourhood of the town, and the population will rapidly increase in the next few years.

Owing to the practice of building houses in flats which prevails in Glasgow, the population occupies a much smaller area than is usual in large towns, London, for example. In London, it has been ascertained that in a district of average density wholly built upon, there are 30,000 persons to one square mile, or about 47 to an acre. In Glasgow, however, the population in the burgh, of which the acreage is 6093, was, in 1874, 534,530, or between 87 and 88 to an acre; and parts of the suburbs are quite as densely populated, having not far short of 100 persons to the acre. This crowding of the population on a small area would make the dry-weather flow of sewage from the inhabited area large in proportion to the wet weather flow, in comparison with less densely populated towns.

The population of Glasgow and its suburbs amounts to about two-thirds of the whole population of the region of the Clyde; and it will be convenient first to consider what is the best mode of dealing with the sewage of this vast population, dwelling on a comparatively confined area, as the mode selected for Glasgow may determine that for one or more of the smaller centres of population.

At the census of 1871 the population of the burgh of Glasgow, together with that of the adjoining small burghs and suburbs which now form a continuously inhabited area with it, was about 570,000. The population of the same district now will not be less than 680,000. The population actually supplied by the Glasgow Waterworks in the year 1874 was, as I am informed by Mr. Gale the engineer, 680,000, and was increasing at the rate of 20,000 a year, so that it is now 700,000. Part, however, though a small percentage only, of the above population which is supplied by the Glasgow Waterworks is not included in the district to which my estimate relates. The quantity of water supplied daily by the Glasgow Waterworks for all purposes amounted in 1874 to 36,000,000 gallons, or 53 gallons per head of the population supplied. Of this quantity, 5,300,000 gallons is the average daily supply throughout the year for manufacturing purposes. Deducting this from the total supply, we have 45 gallons a head as the amount supplied daily for domestic use.

In addition to this large volume of water supplied by the Glasgow Waterworks, which is daily poured by the common sewers into the Clyde after it has been rendered foul by the various uses to which it is applied, there is an average of 10,000,000 gallons pumped from the Clyde for manufacturing purposes, and returned in a polluted state to the river, and also an average of 2,000,000 gallons flowing daily down burns, which pass beneath the streets of the town, and have been made part of the general system of sewers. Thus there is daily a volume of close upon 48 millions of gallons of polluted water flowing into the Clyde through the sewers of Glasgow and its suburbs.

Large as the above quantity of sewage is, it is but a part of the polluted liquid which sometimes flows into the sewers, and by them to the Clyde. As yet I have taken no account of rainfall, and the above is only the dry-weather flow. However good the scavengering and cleansing of a large town may be, there will always remain an immense

amount of filth to be removed from its streets and courts by rain. An inspection of the gutters and bye-streets of any town will make this patent to any one. Analyses of the water flowing in the London gutters have proved it to be as foul as ordinary sewage, when judged by the amount of organic matter capable of putrefaction which it contains. This foul liquid, which is too often lost sight of by advocates of various schemes for dealing with town sewage, must be carried off by sewers; and a system of sewers for this purpose alone is indispensable. The street sewers must, moreover, be capable of carrying off the whole of the rainfall which may at any time occur in the district which they drain, and this will at times far exceed in volume that of the domestic and manufacturing sewage. A quarter of an inch of rain in 24 hours over the inhabited area in question (about 10,000 acres) would amount to 56,560,000 gallons.

It must be obvious that any such partial change in existing conditions as the abolition of the water-closet system, were that practicable or advisable (which it is not), would not reduce the vast quantity of sewage in any appreciable degree, or in any way simplify the question of dealing with town sewage, as some seem to suppose. The volume of domestic sewage might no doubt be reduced; much of the water supplied for domestic use could be restricted; but there seems no hope that the domestic consumption of water in Glasgow can be reduced below 40 gallons a head, or 11 per cent. under the present consumption. The manufacturers might perhaps reduce the quantity of water which they consume, and should be compelled to do so as far as possible.

Intercepting Sewers.

But if these and all other practicable reductions were made in the quantity of water consumed, there would still remain a daily amount of polluted liquid so large that it would be quite out of the question to attempt to deal with it within the limits of the inhabited area. It must either flow to the Clyde as at present, or be intercepted by a new system of sewers, and be conducted by them to some more distant point beyond the inhabited area. These intercepting sewers need not be constructed of a capacity sufficient to take off the storm waters of exceptional rainfalls. When such occur, the storm waters may be discharged by special outfalls into the Clyde; but the sewers must be of sufficient size to take ordinary falls of rain, say up to a quarter of an inch in twenty-four hours. Such a system of sewers I have shown on Plan No. 1. There are two sets of intercepting sewers—a low level and a high level sewer—on each side of the river, with a falling gradient nowhere less than 2 feet a mile in the direction in which the river flows, and terminating near Whiteinch, on the Clyde, about $3\frac{1}{2}$ miles below Glasgow, and beyond its present suburban limits. Separate syphon pipes would have to be laid beneath the bed of the river at this point, to convey the sewage of the high and low level sewers from the north to the south side of the river, where the sewage from the low level sewer could be raised by pumping.

If the Clyde is no longer to be allowed to remain in its present foul condition, some such system of intercepting sewers as I have indicated is necessary, and would have to be carried at least as far as I have shown, whatever scheme were afterwards adopted for dealing with the sewage of Glasgow.

The intercepting sewers I recommend are shown on Plan No. 1, and are calculated to take the whole of the existing sewage of the town, with 50 per cent. increase. They would vary in diameter from 3 ft. 6 in. at the upper end, to 6 ft. 6 in. at the lower end.

Having arrived at the conclusion that these intercepting sewers are necessary, whatever be the means eventually adopted for disposing of the sewage, it remains to be determined how that can best be done, and how the sewage, after being brought to one point on the Clyde, which I have fixed near Whiteinch, can best be dealt with without polluting the river. The four general systems which have been briefly described are the only ones, in my opinion, demanding consideration. One—that is, Filtration—may be dismissed for reasons already stated. Irrigation, as a means of disposing of the whole of the sewage at this place, has next to be considered. The only land in the immediate neighbourhood of Glasgow at all suitable as regards level and contour for irrigation and sewage farming, lies on both sides of the Clyde, just below Whiteinch. Several schemes for utilizing the sewage of Glasgow on this land have been submitted to the Corporation. The soil, however, is not altogether suitable; the rainfall is large; and the cost of the large area of land that

would be wanted would be very great. Moreover, the prevalent winds blow directly over it towards the best quarters of the town, and several thousand acres of land so situated and irrigated with sewage might prove a nuisance greater than the river in its present polluted state. And finally, the quantity of available land at this spot, as will be seen below, would be insufficient for the present amount of sewage.

There are on the south side of the Clyde about 8000 acres of low lying land, extending for a distance of 7 miles west of Whiteinch, and with a width varying from 1 to 4 miles. On the north side there are about 1500 acres suitable as regards level and contour for irrigation. This gives an area of 9500 acres. Experience seems to show that the best results are obtained by distributing 5000 to 6000 tons of sewage over each acre per annum. Taking the dry-weather flow of Glasgow at 48 million gallons a day, there would be 214,286 tons of sewage to distribute daily, or 78¼ million tons yearly, which alone, at 6000 tons to the acre, would require 13,000 acres, and an additional quantity of land would be required yearly for the increasing population. Independently of Glasgow itself, there is a large and increasing population in Paisley and its neighbourhood, in close proximity to this same land, who would have an equal claim to it with the Glasgow district.

I could hardly venture to estimate the difficulty of obtaining such a vast area of land for such a purpose in such a situation, nor the cost of purchasing it if it could be obtained. Even the cost of preparing it for sewage farming would be very large; and I cannot advise, in this case, that an industrial work on so vast a scale as a sewage farm of many thousand acres should, with all its attendant risks, be undertaken with ratepayers' money.

Considering the Filtration and Irrigation systems inapplicable in this case, it remains to be considered whether it would be advisable to discharge the sewage into the Clyde at Whiteinch, after subjecting it to some process of deodorization, or to convey it still farther and discharge it into the river, or Firth of Clyde, or the sea, at some place to be decided upon.

By the addition first of suitable deodorizing and precipitating substances, such as alum, clay, lime, and charcoal, to the sewage, then allowing the solid matter to subside, and afterwards filtering the liquid through prepared filters to be used intermittently, I believe that the whole of the sewage of the district under consideration might be discharged into the Clyde at Whiteinch without causing a nuisance to the neighbourhood. The solid matter precipitated by the process now in operation at Leeds is inodorous, and possesses some value as a manure. The quantity which would be produced annually from the large volume of sewage of the Glasgow district would be very great. The solid matter in only 48 million gallons per day, judging from the average of that contained in four of the principal sewers, would, in a condition suitable for carting, amount to close upon 186,000 tons in one year, and this amount would be largely increased by the addition of the deodorizing and precipitating substances. Messrs. Anderson and Bateman, in their report to the Sanitary Committee of the Town Council of Glasgow, estimate that the lime process of precipitation would increase the solid residue by 2½ times, or to 465,000 tons.

Mr. Napier found that it required 31 tons 8 cwt. of a mixture of alum sludge, lime, and charcoal to deodorize and precipitate 1,000,000 gallons of average Glasgow sewage, which would amount to 550,000 tons per annum for 48,000,000 gallons.

One great objection to the adoption of such a system on so large a scale, when any other is available, is the uncertainty of what it may cost. The price of the materials required for the process would fluctuate from time to time, and would rise as the demand for them increased. The cost of the process must in any case be very great. Taking the experience of Leeds, it would be about £80,000 a year on 48,000,000 gallons per day for pumping, chemical materials, and labour, if the chemical materials could be procured in so large a quantity in Glasgow at the same rate as at Leeds, and assuming that the solid precipitant could be disposed of free of cost. Moreover, though artificial manures of high fertilizing quality bear the cost of carriage to distant places, those of lesser value would be limited to a much narrower area of sale.

The quantity of artificial manure consumed annually in the United Kingdom is not so great as might be supposed. Mr. J. B. Lawes and Mr. James Caird have obligingly

given me their opinion as to the consumption, and they put it at from 700,000 to 800,000 tons, including nitrate of soda and Peruvian guano. If this estimate is correct, and I know of no better authorities on the subject, it is obvious that it would be unwise to enter upon a costly scheme of deodorization with the expectation that any considerable return would be derived from the sale at one spot of four or five hundred thousand tons of an inferior quality of artificial manure.

There remains the further question, whether an enormous amount of products such as would be produced under such a system could be disposed of at all in the neighbourhood. If, as is probable, much of it could not, mounds of it would accumulate on the spot, requiring more expenditure for space on which to put it, and greatly deteriorating the adjoining lands; or it would have to be carried away to some distant place of deposit, such as Loch Long.

On the whole, I have come to the conclusion that it would not be wise to adopt a system of deodorization, and to discharge the effluent water into the Clyde at Whiteinch; but that it will be better to convey the sewage still farther, to an outfall in the river or Firth of Clyde, or in the sea.

AS TO THE OUTFALL.

The decision as to the best point of outfall, and of the best course for an outfall sewer, involves grave questions for consideration, and has occupied much of my attention.

I have made careful examinations of the banks of the river, and of the shores of the Firth of Clyde from Glasgow to Troon, and have examined the region lying between this extent of shore and Whiteinch, the place which I consider the best point of departure for an outfall sewer, to whatever point it may be carried.

Between Gourock and Glasgow there is, I think, no place where it would be possible to discharge a large volume of crude sewage into the Clyde without creating fresh causes of complaint. The class of property along the banks of the Clyde, and the nature of the river itself, are sufficient reasons for this.

Beyond Gourock there are three points of outflow worthy of consideration, viz. Cloch Point, Farland Head, and one near Irvine on the Ayrshire coast. The last was the place recommended by Messrs. Bateman and Bazalgette in their report in 1868.

I have surveyed lines of sewer from Whiteinch to all these places, and a plan and section of each is shown on Plan No. 1.

There would, so far as regards engineering works, be no very material difference in first cost, whichever of these three routes were selected.

In deciding between them, there is one material element for consideration which cannot be neglected.

An outfall sewer to any of those places will be a work of magnitude and of considerable cost, and, when constructed, ought to be calculated to endure.

It must, from circumstances, be constructed with only a small inclination or fall per mile, and it is necessary to carry it as little as possible through lands liable to be undermined by future coal or mineral workings, which, by disturbing the strata, might deflect or fracture the sewer, and hinder its proper working.

Feeling the importance of this question, I directed Mr. Rankine, an experienced mining engineer, to examine the neighbourhood, and to report to me on the extent of minerals yet to be wrought; and I have availed myself of the information thus obtained.

To this source of danger the sewer to the outfall near Irvine would be the most exposed; the sewer to Farland Head and the sewer to Cloch Point would be the most free from objection in this respect.

If this contingency had to be met by purchasing coal or minerals along the line of sewer, it would in course of time add greatly to the expenditure. It is no doubt true that, looking to the possibility of sewage farming hereafter, it might be an advantage to convey the sewage to the sandy soil of the Ayrshire coast; yet the town of Irvine might not appreciate that method of disposing of the sewage of the city of Glasgow. The outfall would be only about two miles from Irvine, and about the same distance from Saltcoats; and although I may be of opinion that sewage delivered into the sea at that distance might not be found to be a nuisance to either of these towns, yet, having regard to the quantity of minerals on the route, and the residential considerations, I think there are objections on the whole sufficient to deter me from advising the adoption of an outfall sewer to that point.

It remains now to consider Cloch Point and Farland Head.

One very great advantage of a sewer to Cloch Point would be, that it would provide on its way for the drainage of Port Glasgow and Greenock. There might, however, be residential objections to that outfall. The land on the shore from Gourock southward is partly occupied by country residences and villas, and the part of the Firth adjoining is used for recreation in yachting and boating by a large part of the population of the Clyde.

After duly weighing every circumstance, and all the possibilities and objections which, so far as I can see, may arise, the conclusion I have arrived at is that an outfall sewer from Whiteinch to Farland Head is the most free from objections. An outfall at that point will be farther seaward than at Cloch Point; and the risk from passing over mineral property, by alterations I have made in the line since I received Mr. Rankine's report, is reduced to small dimensions.

No doubt the adoption of this outfall would subsequently lead to the necessity of constructing an intercepting sewer from Port Glasgow past Greenock to some point down the Clyde.

The cost of an outfall sewer from Whiteinch to Farland Head, of a diameter of 13 feet, will be £1,500,000 (see the estimate in the Appendix). In this sewer I have made provision for the whole of the existing population, which it would serve, together with an increase of 50 per cent. Should the growth of manufactories, buildings, and population hereafter extend down the Clyde below Whiteinch, as it may do, there will be no difficulty in constructing an intercepting sewer from a point 6 or 7 miles lower down the river, falling towards Whiteinch, and there communicating with the outfall sewer to Farland Head.

Districts which would Discharge into the Outfall Sewers.

Glasgow and its neighbourhood, and Paisley, Johnstone, and Renfrew.

The intercepting sewers extending to Whiteinch, and the outfall sewer from thence to Farland Head, would afford the means of disposing of the sewage of Glasgow and the suburban districts which are continuous with it, and form part of the same inhabited area, viz. *North of the Clyde*—Partick, Hillhead, and part of Springburn; and *south of the Clyde*—Govan, Kinning Park, Crosshill, Pollokshields, Strathbungo, Mount Florida, Crossmyloof, Shawlands, Pollokshaws, and Rutherglen; and also that of the detached but neighbouring villages of Maryhill, Shettleston, and Tollcross, which are *north* of the Clyde; and the towns of Paisley, Johnstone, Kilbarchan, and Renfrew, and the villages of Elderslie and Cambuslang, which are on the *south* side of the Clyde. The population of the above towns and villages amounts to about 760,000, and more than two-thirds of this population is comprised within the burgh of Glasgow, of which the population was estimated to be 534,530 in 1874. The area of the Municipal Burgh is 6093 acres, and nearly the whole of it is sewered. The greater part of the sewage is discharged directly by several outfalls into the Clyde. The remainder is discharged into the river Kelvin and the various burns which have been covered in and flow beneath the town. The present outfalls along the banks of the river Clyde are exposed at low water, and masses of filth are deposited on the foreshore.

Hillhead, Partick, Springburn, Govan, Kinning Park, Pollokshields, Crosshill,

Strathbungo, Mount Florida, Crossmyloof, Shawlands, Pollokshaws, and Rutherglen immediately adjoin the inhabited area included within the burgh boundary, but are under separate local authorities. These districts, of which the population has rapidly increased, and is in most cases still increasing, are all supplied by the Glasgow Waterworks, and are sewered. The sewers of Hillhead discharge into the Kelvin; those of Govan, into the Clyde direct; and those of the remaining districts, either into the Clyde or into burns which flow to it, with the exception of Pollokshaws, Shawlands, and part of the Crosshill district, which discharge into the White Cart. Maryhill is situated on the Kelvin, about a mile to the north-west of Glasgow. It has a population of about 6000, who are supplied with water from the Glasgow Waterworks. There are several large manufactories in the town and its immediate neighbourhood, which contribute to the pollution of the Kelvin. Shettleston and Tollcross are small villages lying to the east of Glasgow, having each a population of between two and three thousand. They are supplied with water from the Glasgow Waterworks.

The sewage of Maryhill, Shettleston, and Tollcross would flow by gravitation, without pumping, into the Glasgow high-level intercepting sewer on the north side of the Clyde.

The burgh of Renfrew, which has a population of between 4000 and 5000, is situated on the river Clyde, about 1½ miles below Whiteinch. It has a complete system of sewerage. The sewers discharge by four outlets into the Pudzeoch Burn, which forms the eastern boundary of the burgh. The tide flows up the burn for a distance of about 700 yards from the Clyde, and it is into this tidal portion of the burn that the sewage is discharged. There are only one or two manufactories in the town. It is supplied with water from the Glasgow Waterworks.

The situation of Renfrew is too low to admit of its draining by gravitation into the outfall sewer, and it will be necessary to make a low-level sewer to the pumping station opposite Whiteinch.

Paisley is a large manufacturing town of 50,000 inhabitants. The White Cart is much polluted before it reaches the town, through which it flows, but it receives a large addition to its impurities in its course through Paisley. Provost Murray, whose evidence as to the condition of the town appears in the Appendix, estimates the quantity of liquid refuse daily discharged into the river by the manufactories in Paisley at about one million gallons. Owing to the defective state of the drainage, the river is not largely polluted by domestic sewage; it would be much more so if the town were better drained, as it must be before long. Paisley is well supplied with water from three reservoirs, which have each separate gathering-grounds in the hills 4 miles to the south and south-west of the town. The daily supply amounts to from 2 to 3 millions of gallons for all purposes.

Johnstone is situated on the Black Cart, about 2 miles to the west of Paisley. It has a population of between seven and eight thousand, principally employed in manufactories in the town and neighbourhood. It is supplied with water from the Paisley Waterworks. The town is sewered. The sewers discharge into the Black Cart, into the Pockland Burn, which flows into it, and into the Glasgow, Paisley, and Ardrossan Canal.

The village of Elderslie, lying between Paisley and Johnstone, adjoins and forms a suburb to the latter town. Its population exceeds 1000 in number.

As will be seen by the map, the outfall sewer to Farland Head passes close to Paisley, Elderslie, and Johnstone. A large part of the sewage of Paisley would drain directly by gravitation into the outfall sewer, but that from the lower part of the town would require to be raised by pumping. The sewage of Kilbarchan, a small town of between two and three thousand inhabitants, lying to the west of Johnstone, could be discharged into the outfall sewer, from which it is distant about one mile. The quantity of sewage would be small, however, and it should, if possible, be disposed of on the land in the neighbourhood, as the situation of the town on high ground offers great facilities for irrigation.

The remaining village on the south side of the Clyde without the Glasgow inhabited area is Cambuslang, which has a population of between two and three thousand. It lies about 2 miles to the west of Rutherglen, and is not supplied by the Glasgow Waterworks, but has its own waterworks, the reservoir and gathering-ground being

situated about 2 miles to the south of the town. It may not be advisable at present to conduct the sewage of this population into the system of sewers which will discharge by the outfall sewer, as a large quantity of coal still remains to be worked in the neighbourhood, and there would probably be great settlement along any line which could at present be selected for a sewer. But as soon as a line for a sewer can be found free from this objection, the sewage of the population of Cambuslang can be discharged without pumping by the Glasgow high-level sewer, south of the Clyde, into the main outfall sewer.

I estimate the quantity of domestic sewage and manufacturing waste liquids, which would pass daily into the sewers draining the area inhabited by the population of 760,000, at about 52,000,000 gallons exclusive of rainfall. A quarter of an inch of rainfall in 24 hours, over the area inhabited by the same population, would amount to about 65,000,000 gallons.

COATBRIDGE AND AIRDRIE.

Coatbridge lies about 9 miles from the centre of, and to the eastward of, Glasgow, and is an industrial centre of considerable activity, with a population of about 23,000, including that of the adjoining villages of Whifflet and Coatdyke, and of the immediate suburbs. There is no general system of sewerage, but parts of the town have been well sewered by the owners of the soil. For other parts, plans have been prepared, and an assessment has been made, for a system of sewerage. Other parts are still unsewered. The sewers now in use discharge into the Luggie Burn, which flows into the North Calder.

Airdrie is situated about 1½ miles to the westward of Coatbridge, beyond the village of Coatdyke, which lies between the two towns. It has a population of about 16,000, including the suburban villages of Rawyards, Drumgelloch, and Clarkston. There are few important manufacturing works, and the coal-mining industry in the immediate neighbourhood, which lately received a new impetus, is not likely to increase, but rather diminish, now that the Hamilton coalfields are to be worked. There is no complete system of sewerage; and such sewage as does not soak into the soil finds its way, by covered drains or by open ditches, into the South Burn, and thence to the North Calder.

The whole of the population of Coatbridge, Airdrie, and above-named neighbouring villages, amounting to about 40,000, is supplied with water by the Airdrie and Coatbridge Waterworks from the reservoir at Hillend. The quantity of water supplied daily is about 2½ million gallons. The district supplied by these works is an extensive one, extending as far as the Glasgow water supply district, which it adjoins at Shettleston, and comprises a straggling population, not included in the above estimate. The land in the neighbourhood of the above towns is not very suitable for irrigation as regards the nature of the soil, which is in great part a stiff boulder clay; but there would be no difficulty in finding land for the purpose, conveniently placed with regard to level. In that respect, the land situated to the south of Airdrie, along the Monkland Canal about Hillhead, and to the north end of the town about Kippisbyre farm, seem to be the best for the Airdrie portion of the population. As regards the Coatbridge part of the population, the land most conveniently situated appears to be in the neighbourhood of Old Monkland, along the bank of the North Calder. If it were determined to distribute the sewage of Airdrie, Coatbridge, and their suburbs over the land, it would be necessary to make about 2 miles of sewer, beginning in the centre of Airdrie, to conduct the sewage of that town and its suburbs to a suitable place for the purpose. For Coatbridge and its suburbs, a sewer of about the same length at least would have to be made. Now, a sewer 4 miles long, that is, of equal length to the above-mentioned sewers taken together, if it were begun at the same point in Airdrie, and were made beneath the turnpike road through Coatbridge towards Glasgow, would convey the sewage of both towns to within 3 miles of the Glasgow system of sewers, which would extend to Shettleston. The construction of 3 additional miles of sewer beneath the road through Baillieston to Shettleston would discharge the sewage of Coatbridge, Airdrie, and their suburbs into the Glasgow north high-level intercepting sewer, from whence it would flow by Whiteinch to Farland Head. If, on the other hand, it were determined to deodorize the sewage of these towns, it would be obviously the most economical course to make one work suffice for the two towns, rather than have separate works for each, and about the same length of sewer—namely, 4 miles—would be required, beginning at the same point in Airdrie, and passing through Coatdyke to Coatbridge, to carry the

sewage to a suitable place for the deodorization works. From this it will be seen that the question to be decided in dealing with the sewage of these towns is, whether it would be the better course to make 3 miles of sewer beneath the road to Shettleston, there to join the Glasgow system of intercepting sewers, than to carry out a separate system of sewage farming, or a joint system of deodorization. In the first place, the cost of such a sewer can be ascertained beforehand; and taken as a charge on the rates, it will decrease each year, whilst provision will be made for disposal of the sewage for many years to come. On the other hand, it is impossible to estimate with certainty what the cost of sewage farming or that of deodorization will be. But whatever it may be now, it will be a charge annually increasing with the increase in the population. From the above consideration, it appears to me that the best plan to be adopted for disposing of the sewage of the whole of this population will be to construct a sewer, beginning at Airdrie and running along the line of the high road to Glasgow, to join the Glasgow system of sewers at Shettleston. The total length of this sewer would be about 7 miles. It need not be of large dimensions, as the fall is considerable throughout the whole distance. I have shown such a sewer on Plan No. 1, and included it in the estimate. It will be seen that this sewer will have to be made throughout in a mineral district. Coal is now being worked along the whole line of the proposed sewer; but the fall is so great, that I do not think this is a fatal objection in the case of a sewer of such small sectional area.

Adding the population of Airdrie and Coatbridge to that previously given, will give a total of 800,000 inhabitants. The sewage, including a quarter of an inch of rainfall in 24 hours, will amount to 120,000,000 gallons; and adding 50 per cent. to this, the total quantity will be 180,000,000 gallons in 24 hours, which the sewers have been calculated to take. The cost of the intercepting and outfall sewers appears in the estimate appended to this Report.

There is a scattered population in the villages of Baillieston, Barrachnie, and Sandyhills, along the road between Coatbridge and Glasgow, which might use this sewer if their sewage could not be otherwise disposed of on the land in their neighbourhood. Provision might be made without difficulty for distributing sewage at convenient points along the line of the sewer to farmers, who were disposed to take it and pay for it, which they would probably do more readily if they could have it when they required it, and were not obliged to take a stated quantity at all times, as must necessarily be the case where a large quantity of sewage has to be disposed of on one farm of limited extent.

Disposal of Sewage from other Districts.

The outfall sewer will only provide means for disposing of the sewage of a part of the region embraced in the Commission, as will be seen from the plan which shows the extent of that region. Several towns and villages, and many works and manufactories, will still remain to be dealt with.

It would be plainly impracticable to construct sewers communicating with the intercepting and outfall sewers above referred to from all the outlying towns and villages, or from every work and manufactory. Many of these, therefore, will have to be dealt with locally and by other methods.

Nor would it have been possible for me, without delaying this report for an unreasonable length of time, to have designed precise schemes for every one of these outlying towns and villages, much less for every work and manufactory. In some cases the choice of method may have to be determined by the possibility of obtaining suitable land for irrigation—a question that can only be determined after negotiation with landowners. But I propose to indicate generally what occurs to me as to the principal towns and places, and also the mode in which I would propose the works and manufactories should be dealt with; and before concluding, I shall suggest a system of local government, in respect of sewage, applicable to the whole district, which, I think, would enable the objects aimed at in this report to be best attained.

BARRHEAD, THORNLIEBANK, NEILSTON, BUSBY, AND NEW CATHCART.

It will be seen from the map that there is a group of villages to the south of Glasgow and Paisley, situated on streams which flow into the White Cart. The popula-

tions of these villages supply labour to numerous manufactories, among which are cotton and weaving mills, print works, dye works, and chemical works, some of which contribute to the pollution of the White Cart. All these villages are supplied by the Glasgow Waterworks; but the mills and other works in most cases obtain their water supply from streams and small reservoirs. In some of the works of this district, settling ponds and tanks have already been provided by the owners, to purify, to some extent, the water which they pollute, before passing it into the streams. Ash and other closets have also in many cases been provided for the workpeople. Much, however, still remains to be done, as may be seen from an inspection of the streams flowing to the Cart, some of which are very filthy.

The high-level intercepting sewer on the south side of the Clyde will pass at no great distance to the northward of this district, and would provide a means of disposing of the sewage should the population increase sufficiently to prevent its being easily disposed of in other ways. Barrhead had, at the last census, a population of about 6300; Thornliebank came next in size, with a population of 2100. As the population of these places is not large, the sewage could perhaps be disposed of on the land in the neighbourhood; though the sewage of Barrhead might be cheaply disposed of by constructing a short sewer to the outfall sewer at Hurlet.

WISHAW, MOTHERWELL, AND NEIGHBOURING PLACES SOUTH OF COATBRIDGE AND AIRDRIE.

South of Coatbridge and Airdrie, in the mining district lying between the North and South Calder, and between the latter river and the Clyde, there is a large population employed in raising coal and in various works principally connected with the manufacture of iron. This population is collected in scattered places, of which there are 13 having a population of 1000 and upwards, and many smaller ones, supplying labour to the large ironworks situated throughout the district.

The names of the principal places in this district are,—Wishaw (including Craigneuk), Motherwell, Bellshill and Mossend, Calderbank, Holytown, Calder Iron Works, Chapel Hall, Newarthill, Newmains, Cambusnethan, Carfin, and Dykehead.

The whole of the sewage of these places is discharged, with one or two exceptions, directly into the streams of the North and South Calder or their tributaries. Throughout this district water-closets are the exception, the privy and midden system being generally adopted, and it is not likely that there will be any change made in this respect. The water supply is very inadequate at present. Wishaw is the best off in this respect, being supplied by a reservoir of its own, distant about four miles from the town. The population of Wishaw, together with that of Craigneuk, which is now included within the boundary of and forms part of Wishaw, amounts to 15,000, showing a large increase since the last Census. The water supply amounts to 16 gallons a head. Cambusnethan is also supplied by the Wishaw waterworks. The only other place which has a systematic water supply is Motherwell, of which the population is now about 7000. Motherwell is supplied, by an arrangement made with the Caledonian Railway Company, at the rate of about 8 gallons per head, the water being pumped from the Clyde. I understand that a comprehensive scheme is now under discussion for supplying these places with water, as also Bothwell, which lies more to the westward, and is at present supplied by shallow wells, which will probably become dry as more pits are sunk in the neighbourhood. I do not recommend that the sewage of these towns and villages be dealt with as a whole. The quantity produced at each place will generally be small in proportion to the population, and will be best disposed of on the land in the neighbourhood, after the solid and more offensive parts of the sewage have been removed, or after the sewage has been deodorized, where the land available for irrigation is in proximity to human habitations.

The sewage of Wishaw has for many years been disposed of on the land by irrigation. The principal portion of it is conducted, partly by a covered drain and partly in an open ditch, to the Carbarns farm on Lord Belhaven's estate, on the north bank of the Clyde, about two miles from Wishaw. The conduits, as far as the burgh boundary, were made at the expense of the burgh authorities, who advanced £100 towards the further extension of them to the farm. For the last fifteen years the sewage has been distributed over the farm at a profit to the owner. The sewage of Cambusnethan was likewise for a time

conducted to some meadows near Coltness House, but for the last two years it has been allowed to flow into a burn, and from thence to the Calder. At Motherwell there has been no systematic attempt at irrigation, but farmers take sewage on to their fields from three of the principal outlets. I can see no reason why the whole of the sewage of the district should not be disposed of on the land.

HAMILTON.

Hamilton is situated on the south side of the Clyde, at a distance of about 8½ miles by road from Rutherglen, which I have included in the Glasgow system of drainage. The population of Hamilton is now 12,000; but, as before observed, it is likely greatly to increase in the next few years. It is supplied with water by works situated on the high land to the south-west of the town. The present supply amounts to about 20 gallons a head, but an Act has been obtained to authorize the construction of new reservoirs, which will double the present supply. The water-closet system does not prevail extensively, and it is not looked on with favour by the authorities. There is a good system of sewerage throughout the town, by which the sewage is discharged into the Clyde, principally by the means of the Cadzow Burn, which has been partly covered in.

I have considered the propriety of making a sewer, and have made trial sections for one, from Hamilton to join one of the Glasgow intercepting sewers at Rutherglen. But there are several objections to this course. A considerable length of such a sewer would necessarily be over coal workings, where the seams of coal are thick and lie near enough to the surface to disturb and fracture the sewer. The work would prove too costly for the population to be served at present, more especially if it were constructed to serve the probable large addition which will be made to the population of Hamilton and the district lying between that town and Glasgow, on the south side of the Clyde, in succeeding years, when the rich coal beds beneath it are worked. There is no land near the town available for irrigation, except that forming part of the park to Hamilton Palace, or in its immediate neighbourhood. It is probable, therefore, that the sewage of Hamilton will be best disposed of by some deodorizing process, expensive though that may be.

GREENOCK AND GOUROCK.

Greenock is situated on the south bank of the Clyde, about 20 miles below Glasgow Bridge. The town lies partly opposite to and extends for two miles beyond the last shoals which are exposed at low water from Dumbarton downwards. After Glasgow, it is the most important town in the region of the Clyde, having a population of about 65,000 (1875). It is well supplied with water from large reservoirs in the hills behind the town. These waterworks, besides satisfying the demand for domestic and manufacturing purposes, supply water-power to many manufactories in and about the town. The supply for domestic purposes only amounts to 50 gallons per head, the water-closet system being in general use. Part of the Greenock water supply is drawn from outside the area which I have included in the region of the Clyde, as will be seen by a reference to Plan No. 2.

The gathering ground of this water supply is at the head of the burns which discharge into the Firth of Clyde about Innerkip and Wemyss. But a part of the supply is drawn from two reservoirs, which receive the drainage of about 2413 acres, at the head of the Gryfe Water, a tributary of the Black Cart river.

For sewerage purposes the town is divided into ten districts, there being a separate outfall to the sewer of each district. Three of these outfalls, draining the central districts, discharge into deep water along the river quay, where the current is strong, so that the sewage is soon lost in the large volume of water with which it mingles. A fourth outlet, also from a central district, discharges into the East Dock. This sewer brings down a large amount of refuse from sugar and chemical works. Two outlets to the eastern districts, one on each side of Garvel Point, discharge on the foreshore between timber ponds, and render the mud exposed at low water very offensive. The four remaining outlets are opposite the esplanade, near the best residential property in the town, which would be greatly benefited by their being taken to some other point of discharge, by the construction of an intercepting sewer along the foreshore.

Although the Clyde may not at present appear to be greatly polluted by the sewage of Greenock, as the expanse of water in front of the town is great, and the deep-water channel of the river, along which there is a strong current at the ebb and flow of the tide, passes close by the sewer outlets, yet, as the population increases, or the river above is more contracted by artificial embankments, the sewage will be carried by the tide higher up the Clyde, and improved drainage will become necessary.

To do this, if the outfall at Farland Head were adopted, an intercepting and outfall sewer would require to be made from Port Glasgow to some distant point below Greenock.

Gourock, which has a population of between 3000 and 4000 inhabitants, is almost a suburb of Greenock, and lies about a mile to the westward of that town down the Clyde.

After what has been said with respect to Greenock, it is needless to consider Gourock in connection with the pollution of the Clyde. It would naturally be included in any scheme for conveying the sewage of Greenock to an outfall farther down the Firth.

PORT GLASGOW.

Port Glasgow is situated on the Clyde above Greenock, and almost adjoining that town, the intervening space along the river margin being occupied by timber ponds, manufactories, and scattered habitations. It has a population of about 11,500 (1875). The town is supplied with water from reservoirs in the hills behind it. The daily supply amounts to about 408,000 gallons. The sewage is discharged by one principal outlet into the deep water of the main river channel, which passes close to the shore in front of the town. Above this principal outlet there are three small pipes, which discharge a small quantity of sewage into the river.

Port Glasgow is somewhat nearer the narrow part of the river above Dumbarton than Greenock, and sewage from Port Glasgow might be carried by the flowing tide into that part of the river. Before many years elapse, it is probable that the inhabited areas of Greenock and Port Glasgow will coalesce. The observations I have made with regard to Greenock apply to this town.

HELENSBURGH.

Helensburgh is situated on the Clyde, opposite to Greenock, and near the entrance to the Gare Loch. The ground on which it is built rises steeply from the water's edge, and as the town has been regularly laid out with parallel rows of streets and cross streets at right angles to them, it is easily drained, and has been sewered throughout.

The sewage is discharged by five outlets on the beach in front of the town. And although it cannot be said at present to add appreciably to the pollution of the Clyde, as the Clyde opposite Helensburgh is three miles wide, the present position of the outlets is objectionable. Helensburgh owes its existence to its being a place to which the people of Glasgow resort for health and recreation, and it would be to the advantage of the town to remove the present outfalls, by constructing an intercepting sewer, which would discharge the whole of the sewage, after deodorization, at a point more distant from the town; or to dispose of it by irrigation.

DUMBARTON AND VILLAGES ON THE RIVER LEVEN.

Dumbarton is situated on the Leven, near its junction with the Clyde. It has a population of about 13,000. There are eight manufactories in the town, consisting of shipbuilding yards and foundries, which cause pollution to the river by the sewage of the people employed in them, which is discharged by private drains into the Leven. The town is sewered, the whole of the sewage being discharged by several outlets into the Leven. The drainage is not good, owing to the low situation of the town, which causes the sewage to back up in the sewers.

Dumbarton is well supplied with water from the hills which rise to a considerable elevation to the north-east of the town. The supply amounts to about 26 gallons a head for domestic and trade purposes. Owing to the low situation of the town, no change could be made in the present mode of disposing of the sewage without having recourse to pumping.

The quantity of sewage, as compared with the volume of the Clyde, is not large; but at present much of the sewage, which is discharged after the time of low water, must find its way up the narrow, embanked part of the Clyde, and add to the pollution of that river. By constructing two intercepting sewers along each side of the Leven, the sewage of Dumbarton might be conveyed to the Clyde, and be there discharged after deodorization. It would be better, however, if land could be procured at a reasonable cost to pass the sewage over it. There is land of a suitable nature along the road from Dumbarton to Bowling. There would be no difficulty in bringing the sewage of that part of the town which lies on the right bank of the Leven across the river by means of a pipe, so as to have one pumping-station on the left bank only, from which the sewage might be distributed over the land in question.

There is a population almost equal to that of Dumbarton inhabiting the villages of Alexandria, Renton, Bonhill, Jamestown, and Balloch, on the banks of the Leven above that town. The villages are partially sewered, and the sewage is conducted by sewers or by open ditches to the Leven. As the water supply is not large, being in most cases from springs in the neighbourhood, the amount of sewage is not great. The villages are very close together, and the ground attached to the residences along the banks of the Leven leaves little land available for irrigation. In order to remove this source of pollution from the Leven, it would be necessary to construct one or more small intercepting sewers along each bank to points where plots of land can be obtained, if not of sufficient acreage to admit of irrigation, at least large enough to permit of the sewage being chemically treated, and afterwards discharged into the Leven. The principal pollution of the river Leven arises in the Turkey-red dyeworks which line its banks.

Seven of the largest of these works on the Leven together pollute daily from 8 to 9 million gallons of water, drawn in the first instance from the river. Some of these mills have done much to purify their refuse liquids before allowing them to flow into the Leven, but much still remains to be done. As regards these works, they should be dealt with in the manner hereafter suggested in the General Provisions.

DUNTOCHER AND FAIFLEY, AND OLD KILPATRICK.

Duntocher and Faifley, with the small villages of Hardgate and Milton, are situated on the high ground bordering the Clyde, about half-way between Glasgow and Dumbarton. These villages, which closely adjoin one another, have a population of about 2500, and supply labour to some large cotton mills and other works situated on the Duntocher Burn, which flows past them. They are supplied with water from waterworks having a reservoir in the hills about two miles to the north. The population is not increasing, and several of the mills are not working at present. The sewage from these villages is now discharged into the Duntocher Burn; it should be disposed of on the land in the neighbourhood, which, as regards level, is well adapted for receiving it.

Old Kilpatrick is a small village on the north bank of the Clyde, about six miles below Whiteinch. It is situated on low ground, but not so low as to prevent the sewage, which is now discharged into the Clyde, being distributed over the adjoining land.

The only other village on the north bank of the Clyde which need be mentioned here is Yoker. The population of Yoker was 535 at the census of 1871; but it has largely increased since then, and is now about 2000. The situation of this village is very low, and there might be some difficulty in obtaining land on which to distribute the sewage. Yoker will be well provided for by the low-level sewer which, as I have before stated, can be made along the Clyde to the westward of Whiteinch as the population extends in that direction.

LENNOXTOWN, KILSYTH, AND KIRKINTILLOCH.

These places contribute to the pollution of the Kelvin.

Lennoxtown is situated on the Glazert, a tributary of the Kelvin. Its population, which at the last Census was 3717, is not increasing. There are three outfalls from the public drains, which, together with several private drains, discharge into the Glazert. This stream is considerably polluted before it joins the Kelvin by refuse from manufactories both above and below Lennoxtown. In Lennoxtown there are only two works, a calico print and an alum work, in both of which an attempt, though not a very effectual one, has been made to keep a part of the refuse from the stream. The present water supply is defective, being obtained from a burn and from wells; but waterworks are being constructed which will give a good supply. The town lies low, but there is land, suitably situated as regards level, below the town, on to which the sewage, which is necessarily small in quantity, might be discharged.

Kilsyth has a population of about 5000, to which the coal mines in the neighbourhood of the town afford employment. The water supply is from the hills, whence it is brought to the town by a 6-inch pipe. There are two sewers in the town, which discharge into a burn flowing into the Kelvin. The town is so situated that the drainage might without difficulty be discharged on neighbouring land.

Kirkintilloch has an increasing population, amounting now to about 7000. The town is well supplied with water from a reservoir in the hills some miles distant. These works also supply Milton, a village on the Glazert, and a scattered population south of the town. Kirkintilloch is well sewered. The sewers discharge by several outlets into the Luggie Burn, which joins the Kelvin close to the town. There is one small drain which discharges direct into the Kelvin, partly along an open ditch. The town is well situated for discharging its sewage on land in the neighbourhood.

The Upper Region of the Clyde.

LANARK.

Lanark is the only town of importance in the upper part of the region of the Clyde. It contained, at the last census, 5099 inhabitants, and there has been no great increase since then. There are no works or manufactories in the town, but just above it, on the river Clyde, there are several large mills.

The town is supplied with water by waterworks belonging to the Corporation. The water is pumped for a distance of about a mile from a loch into a high service-reservoir situated in the upper part of the town.

Lanark is sewered. There is one large main drain passing along the principal street, and discharging on to some meadows about half a mile from the town. There are also two smaller outfalls, one in a field on the south side of and close to the town, the other not far from it, and from which part of the sewage is discharged on to fields, and part into a burn which flows into the Clyde. The greater part of the sewage is now distributed over grass land, but the arrangements for distribution are not good. The sewage from the main drain flows in an open gutter by the side of the high road for some distance after leaving the town. There could be no difficulty whatever in distributing the whole of the sewage over land in the neighbourhood, as the town is admirably situated for the purpose.

OTHER TOWNS AND VILLAGES.

There are a number of small towns and villages, as will be seen by reference to the plans, having a population of less than 3000, and one or two somewhat exceeding that number. It will not be necessary for me to allude more particularly to these. There can be no difficulty in dealing with the small quantity of sewage which they produce, which may in all cases be distributed over the land. In some few cases this has been already done, though not systematically. At Carluke, which has a population of 3400,

the sewage from one of the outlets is distributed over a field of 3 acres, which produces good crops of grass. The only place having a population much exceeding 3000 is Larkhall, which has a population of close on 5000. This village is composed almost entirely of miners' cottages. The only sewage from it would be the slops thrown into the open gutters in front of the cottages. As the village stands high, this source of pollution might easily be got rid of on the adjoining fields.

WORKS AND MANUFACTORIES.

An examination of Plan No. 2 will show how widely these are distributed over the area to which my inquiry relates.

They cause a vast amount of pollution to the streams and rivers on the banks of which they are placed.

Many of them would be gainers by the abatement of this ever-growing nuisance. A work or manufactory placed near the source of a stream gets water pure and clear; it transmits it to its next neighbour more or less polluted; this, and the works still farther down, add new increments of pollution, until at last—as, for instance, in the case of the White Cart—the water, where it enters the Clyde, is exceedingly foul.

It is evident that those works and manufactories situated on the lower portion of the streams suffer from the pollution arising from those above them; and assuming all were treated alike, and every one of the works and manufactories were compelled to return the water into the streams practically free from pollution, the generality of the owners would be gainers thereby.

The question remains, Is it practicable to obviate this state of things with a due regard to manufacturing interests? And the conclusion I have arrived at is, that to a large, and, as I think, to a sufficient extent, it is quite practicable.

In some manufacturing districts the mills are situated in narrow valleys, where little land exists at or about the level of the streams, on the banks of which they are built, and where the mills are so close to one another that it would be sometimes difficult for the millowners to acquire the land which will be necessary for the construction of settling ponds and filters for the purification of their waste liquids. Such cases do not often occur in this district, where, although examples are not wanting of narrow valleys with little level land near the water's edge, the manufactories are generally scattered, and stand in close contiguity only in the neighbourhood of towns, where they might be permitted to use the town sewers under certain restrictions. There are very few cases in the region of the Clyde where a sufficient quantity of suitable land could not be found near the manufactories. The greatest difficulty might occur in the case of the mills on the Leven; but even there the mills are not so close to one another, nor the physical contour of the land such as to prevent the manufacturers doing in the neighbourhood of their works all that is necessary to prevent their liquid refuse from polluting the river. The mills on the Leven are principally Turkey-red dyeworks, a class of work in which as much water is daily used and polluted as in any process of manufacture; yet in one of the largest of these works, belonging to Messrs. John Orr Ewing & Co., measures, which do them much credit, have been taken by them to prevent the Leven being polluted by the discharge from their works. The water so discharged, it is said, has been brought up to the standard of purity suggested by the Rivers Pollution Commission in every respect except one. The matters in suspension still exceed the given standard. Even this last remaining cause of pollution might possibly be remedied by rapid filtration, as was suggested by the Rivers Pollution Commission in their Fourth Report (1872).

The most polluted liquids can almost always be dealt with within the limits of the works. Where land is not available for dealing with the less polluted but more voluminous refuse liquids, as is the case now in other districts, and may be the case as manufactories increase in number in some parts of this, it may be useful for the owners of works to combine to construct a common conduit to some point where there is suitable land, or to the nearest system of sewers.

Attempts have been made with more or less perfect success to purify the waste liquids produced by nearly all the different manufacturing processes which add to the pollution of our rivers and streams; but such attempts have rarely been made by manufacturers until they have been compelled to make them by those interested in the purity of the streams which they pollute. Manufacturers are at present at the mercy of riparian owners of land along the streams on which their works are situated, and may be compelled by them to close their works, or comply with the demands of such owners with regard to the purification of the polluted liquids from their works.

On several of the rivers of Scotland, action has been taken by the riparian owners, and the manufacturers have had to comply with their requirements. On the river Almond, the proprietors of some large paraffin works, after trying other and simpler modes of purification,—none of which were effectual enough to satisfy the chemists appointed by the Court to protect the riparian owners,—were obliged to make arrangements for evaporating the whole of the water, including the rainfall, passing from the part of the works liable to pollution during the process of manufacture. The area subject to pollution was 35 acres in extent. Fortunately, a large quantity of water is necessarily evaporated in this process of manufacture, otherwise the cost of applying such a remedy might have made it impossible to carry on the works at the locality in question. I should mention that from some of the waste liquids evaporated at these works valuable products are recovered; but still the processes necessary to prevent pollution in this case are not remunerative, but a source of loss to the manufacturer,—a loss which is aggravated by the fact that it may fall on one manufacturer and not on another. The owners of paraffin works would suffer no great hardship if they were *all* compelled to dispose of their polluted water on the works,—an opinion already expressed by the Commissioners on the Pollution of Rivers in their Fourth Report.

The papermakers on the river Esk are now being compelled by process of law to abate the nuisance which arose from the discharge of the waste liquids from their works into the river. The most filthy liquids are now all evaporated, and some of the less filthy are used again until they can in turn be evaporated. The products recovered after evaporation pay the cost of this remedy. The least polluted liquids are conducted to settling tanks, from which they flow into the river after depositing a part of the impure matters which they contain. Owing to the large volume of these less polluted liquids, the process of purifying them must necessarily be a cause of expense to the paper manufacturers, and they complain, and not without some reason, that they should be compelled to incur the expenditure thus imposed upon them, while others in the same trade, with whom they have to compete, are permitted to escape similar requirements.

In many cases the chemical matters in solution can be recovered at a profit. One manufacturing chemist in Glasgow informed me that he was now annually recovering, by a simple process, valuable products worth £500 per annum, which he had hitherto allowed to run to waste into the sewers. Most of the stronger solutions produced in the various manufacturing processes, and now contributing largely to the pollution of rivers, can be evaporated or purified by precipitants without expense to the manufacturer, as the value of the waste products recovered will cover the cost of the process. Many examples of these processes are given in the Rivers Pollution Commissioners' Reports. The weaker solutions may be used to form the stronger ones, and by this means, without inflicting any hardship on the manufacturer, the most polluting liquids may be kept from the river, and even where the products recovered from solution by these operations do not repay him, as they sometimes may not, he will often gain largely by the improved condition of the river.

To deal with the large quantities of water containing matter in suspension or used for washing, as in print and dye-works for instance, will be more troublesome to manufacturers, for they cannot hope in any case to reap any benefit beyond the improved condition of the river; though this, in some cases, will be an advantage. Some of these waste liquids contain so little impurity that they may be discharged into the river at once; but in some cases, settling ponds and filters will have to be provided, or chemical precipitants will have to be used. In the printworks of Mr. Thom, situated near Chorley, in Lancashire, which I visited, chemical precipitants and settling reservoirs are used. The process of purification adopted by Mr. Thom is largely successful, and Mr. Thom says he disposes of the products of his process so as to afford him a profit.

The most notable case that I have examined, of how much may be done in a small

space, may be seen at Mr. Biggar's works and mill at Dalry. Much of the wool there used is largely saturated with grease and tar, and the water used in the cleansing processes was for a long time returned to the river greatly polluted.

By processes adopted by Mr. Biggar, and explained in the Appendix (pp. 21, 22), not only the pollution so caused, but also that previously arising from the fœcal matter of the work-people, is now got rid of. Mr. Biggar candidly stated that he did not undertake to remedy the evil until he was compelled by law (at the instance of some of the proprietors on the stream below) to do so.

The space occupied by the processes adopted at the Dalry Mills for remedying the evil is small, and the first outlay not large. Accordingly, Mr. Biggar assured me that the improvement thus effected, so far from costing him anything, is now producing a profit.

The Turkey-red dyeworks at Blantyre have, at a trifling cost,—judging from the appearance not exceeding £100,—obtained the means of abstracting the fatty matter from the water before passing it into the river, and they dispose of the grease so obtained for £8, 10s. per ton. I do not mention this case as making a sufficient provision for the evil to be remedied, for the method is rude and of a temporary character, but only as indicating the direction in which the necessary improvements will have to be carried, and that they can in many cases be effected by ascertained and inexpensive methods.

I might give many other instances, which have come under my notice in the course of this investigation, of works in which steps are being taken to recover the products contained in the more polluting liquids hitherto discharged, with few exceptions, into the rivers. Since so much attention has been given to the subject of pollution, new processes are continually being found by which these waste products can be made available at a profit; but manufacturers, and the large ones more especially, who most contribute to the pollution of rivers, will not, for the sake of the small addition to their incomes to be derived from the recovery of these waste products, be at the expense of recovering them.

In Paisley, an enterprising chemist has undertaken to recover the grease and fatty matter from the waste liquids of manufactories in that town, and is now doing so for several manufactories at a profit to himself derived from the grease which he recovers.

Manufacturers should be encouraged to reduce the quantity of water used in their works as far as possible. A fixed standard of purity might tend to increase rather than diminish the consumption, for it would often be easier for the manufacturer to dilute his refuse liquid by the addition of pure water, until it was above the standard of purity, than to adopt means to remove the impurity before passing the liquid into the river. By such a course much impurity would be unnecessarily passed into the river.

Few waste liquids from manufacturing processes are suitable for application to land for agricultural purposes. Those from distilleries form an exception. They are excessively polluting, and their volume is so great that it has been found, after trials where the owners have been compelled by law to purify them, impossible to deal with these waste liquids in any manner so as to make them sufficiently pure to be discharged into a river. Fortunately the manurial value of this refuse, or 'pot ale' as it is called, is very great. The success of the Carbarns Farm, over which the sewage of Wishaw is distributed, is mainly owing to the high fertilizing power of the sewage consequent on its receiving the discharges from a distillery.

WATER SUPPLY IN RELATION TO SEWAGE.

In the foregoing remarks upon the principal centres of population in the region of the Clyde, I have given some particulars respecting the water supply in all cases where any systematic supply existed, and I have added a Plan showing the position of the reservoirs of the different waterworks, the drainage areas which supply them, and the districts supplied by them.

The questions of water supply and sewage are intimately connected, and there are one or two important points involved in this connection which demand some consideration.

The physical conditions of the region of the Clyde are such as to render it possible to obtain readily an abundance of water at almost any point within it. It is generally surrounded by large tracts of uncultivated land, rising to considerable altitudes, and in most parts favoured with an abundant rainfall.

The water which is impounded in reservoirs for the use of the population is, after supplying their wants, allowed at present to run into the rivers and streams which flow into the Clyde, or into the Clyde itself. As in most cases the water so impounded is such as would flow off quickly in time of floods, it is obvious that the construction of waterworks tends to diminish the quantity of water flowing down the river in flood times, and to increase the ordinary or dry-weather flow.

The construction of an outfall sewer would divert a certain volume of water daily from the Clyde, and it is necessary to consider, and I have considered, whether the diversion of so much water as will flow along the sewer will affect the scour and navigation of the upper reaches of the river.

No doubt the downward flow will be *pro tanto* diminished. On the other hand, the large amount of deposit now carried into the Clyde by the existing sewers will be got rid of, and, on the whole, the one will, I think, compensate for the other.

The storm waters, in rainy seasons, would still pass into the Clyde, and that river is, in my opinion, kept open more by the influx of tidal water than by the downward flow of upland water. Moreover, the Glasgow Waterworks' Commissioners are under obligation to remove the dam or weir which crosses the river above the Glasgow bridges. If this were done, more tidal water would then flow up it, and increased scour would be thereby obtained.

On the whole, I am persuaded that there need be no fear of injuring the navigation of the Clyde by intercepting so much of the sewage as I propose to do, and passing it by the outfall sewer to any of the outfalls referred to.

But although I do not think that the quantity of sewage which will be diverted from the Clyde into the outfall sewer will injure the navigation, it may be necessary to place some restrictions on the use, for manufacturing purposes, of the water of the rivers and streams in cases where the water, after being used, will pass into the outfall sewer, and will not be returned to the source from whence it was derived. At present, the filthy condition of the Kelvin, White Cart, North Calder, and other streams renders them unfit for use for manufacturing purposes, and manufacturers draw their supply from waterworks instead. But if the rivers and streams in question are made, by the proposed measures, sufficiently pure to be used for manufacturing purposes, manufacturers will, in many cases, have recourse to them rather than pay for water supplied from waterworks. The result may be, that if manufacturers are allowed to discharge the water which they have used and polluted into the sewers, which are connected with the outfall at Farland Head, too large a portion of the water of such rivers and streams might be intercepted from passing into the Clyde. To prevent this occurring, it might be necessary, in some cases, to prohibit the discharge of water into the sewers, where it had been obtained direct from a water-course, and not from reservoirs or waterworks providing a compensation flow.

If the measures which I propose for purifying the water-courses of the region of the Clyde are carried out, manufacturers will be divided into three classes:—

1. Those who, from whatever source they obtain their water supply, will be compelled to take measures for purifying so much of it as they may have polluted.

2. Those who, being supplied by waterworks in towns, are permitted to discharge part or all of the water which they pollute into the town sewers.

3. Those who, while they have the advantage of the use of the sewers for getting rid of the water which they pollute, obtain their water direct from streams in the neighbourhood of their works.

Those in the third category will obviously have an advantage over the others, and it will be no hardship to deprive them of the use of the sewers, as I have suggested, and oblige them to return the water, to which they have no exclusive right, in a pure state to the source from whence they took it.

GENERAL REMARKS.

I have not attempted to enumerate all the various kinds of works and manufactories which contribute to the pollution of the streams and rivers of the Clyde district, nor all the mechanical or chemical processes which have been tried or recommended as means for purifying the liquids hitherto run to waste in such works and manufactories. The works and many of the processes in question are described in the valuable Reports of the Rivers Pollution Commission, to which I beg to refer. I have made myself acquainted with previous inquiries, and have obtained information enough, I think, to justify me in believing my recommendations to be practicable of application, and that, if they are adopted, they will secure the end in view.

Those who own and manage works and manufactories have them wholly under control, and can therefore provide and enforce the necessary provisions and regulations for removing the nuisances which they so often create.

There can be no necessity whatever for the fœcal matter from such establisments being passed into streams.

The earth closet with its various modifications, the Colquhoun closet,—first adopted in Paisley, I believe,—and other systems, render this source of pollution one which should at once be put an end to in manufactories. In many works which I have visited, more or less perfect arrangements have been made for keeping this source of pollution from running water. The most perfect which I have seen, and already alluded to, is a modification of the Colquhoun system, contrived by Mr. Biggar, and in use at his mill at Dalry, in Ayrshire. I have seen no works or manufactories in which there is not ample space to provide arrangements of this description.

Manufacturers cannot, however, so readily provide remedies in some other cases. When large volumes of water are made foul each day, they may often find it difficult to obtain space for purifying them, and some provision may be necessary to meet instances of this kind, such as means of acquiring land under Provisional Order, or other compulsory powers. The want of room will, however, chiefly occur in towns where, in most cases, and under proper regulations, the sewers can be made use of.

The Pollution of Rivers Commission, in their Reports, give a number of analyses of sewage, and of the effluent waters from sewers, which have been treated by different processes of deodorization. They also recommend certain standards of purity (determinable by chemical analysis) which the effluent water should not be allowed to fall short of, and give tables of the minimum quantities of noxious matters which the effluent should be permitted to contain. These quantities are minute, and it would require very careful analysis to estimate them, and be difficult to get chemists to agree on the quantitative analyses.

Mr. Crookes, who is an eminent chemist, suggests a more simple test for the purity of the effluent water, and he hopes, by the addition of various mineral substances to the sewage, to produce an effluent which shall bear such a test, viz.: 'That the effluent water shall be clear, that it shall neither taste nor smell, and that fish shall be able to live in it.' Most people would, perhaps, consider water which stood this test to be sufficiently pure. Still, where the presence of poison is suspected, *e.g.* in the case of the liquid flowing from works where arsenic is used in the process of manufacture, it would always be necessary to have recourse to chemical tests. Small quantities of such matters, so small as to be incapable of detection otherwise than by a chemical test, might be exceedingly injurious to health.

In a matter involving such paramount interests it will be prudent to proceed by steps. I see no difficulty in greatly improving the state of the Clyde and its tributaries,

so as to remove the palpable and crying evils experienced by those who reside near them; but absolute purity, if ever attainable, must be a result of time, and await the progress of invention.

In the present state of science and of knowledge on this complex subject, and during the time when new methods and processes are being propounded from day to day, to stereotype further than may be necessary any of those processes would be unwise. It is better to leave parties from time to time to adopt the best then known, and to raise the standard of purity as experience may warrant.

Of course it may, and perhaps will, be said that I am proposing extensive works which future knowledge may prove to have been unnecessary. All I can say on this point, in addition to what I have already said, is that I cannot imagine any system which will in this case render the works I have suggested unnecessary or useless. Unless the fæcal matter could in Glasgow be separated from the rainfall, I see at present no method of making it useful and avoiding a great nuisance except at larger cost; and I know of no mode of separating it which would be tolerated in such towns as Glasgow and Paisley. If hereafter it should be proved that the sewage in the state it arrives at Whiteinch, or passes from thence along the outfall sewer, is sufficiently valuable to justify the expense, and the adjoining landowners are willing it should be so applied, it could be lifted by pumping and used for irrigation on the adjoining lands.

The advocates of several processes of deodorization think they may be worked at a profit. I have as yet found no proof of this. At the same time, I should not deem such proof necessary in order to justify their use in some cases. Outfall sewers are not sources of profit. The question to be determined in each case is, What is the best available method for adoption, cost being a great but not the only element in the consideration? Deodorization and irrigation schemes may be applicable and suitable in cases where it can be shown that no better and cheaper methods can be found. It is not necessary to prove, though it would be a happy circumstance if it could be proved, that the pollution of streams and rivers can be prevented, and the sanitary condition of towns and villages improved, without cost. Expenditure within reasonable limits will have to be and ought to be incurred wherever it becomes necessary.

I am not aware of any, and indeed I feel confident there is no single method of dealing with this question capable of universal application.

The engineering works which in this case I have recommended—by which I mean the intercepting and outfall sewers—will provide for a portion only, though a most important portion, of the large district under consideration. The remaining portions will have to be dealt with in other ways. Taking a wider view of this question, and looking beyond the district of the Clyde, there are towns and villages in the Midland Counties where there is no sea within reach, and where, if prohibited from discharging sewage into their river, they must have recourse to systems of irrigation or deodorization, or some other method. Some of the places in the region of the Clyde are in a like predicament, and cannot avail themselves of the intercepting and outfall sewers I have recommended. These can, I think, be dealt with under the General Provisions which I propose shall be applicable to the whole district.

The region of the river Clyde can be well defined, by making it embrace nearly the whole area within the watershed of that river and its tributaries. I think the Government ought not, and I shall assume that they would not, undertake the onerous duties pertaining to the direction of sanitary works of such a varied character as would be required throughout the area in question.

Such duties would, I believe, be better performed by Local Authorities already constituted, or to be constituted, with control over enlarged districts where necessary, and with a constitution somewhat similar to that of the Metropolitan Board of Works of London.

SUGGESTED GENERAL PROVISIONS.

I proceed finally to state the general provisions which I recommend should be made to secure as far as practicable the purification of the Clyde and its tributaries. Although

much might be done by the individual action of the sanitary authorities in the different localities, I am strongly of opinion that much time and money will be saved, and earlier and better results will be obtained, if a body be formed having jurisdiction over the whole region draining into the Clyde, and armed with authority to prevent the pollution of its waters.

1. I therefore recommend that, in the first instance, there should be constituted a Board of 'Sanitary Commissioners of the Clyde,' to consist of representatives of the various Town Councils or sanitary authorities within the area indicated on the Plans attached to this Report. The number of the Commissioners should not exceed thirty-six, and they should be allotted among the various authorities as nearly as possible in the ratio of the rateable value of the property within their respective districts. In some cases, two or more of the smaller authorities should be combined for the purpose of electing a representative. The Commissioners should have power to appoint and pay the necessary officers, and to make requisitions upon the different rating authorities for their quota of the expenses incurred, for which an efficient audit should be provided.

2. It should be the duty of the Sanitary Commissioners to compel the various local authorities, as well as individual owners, to take steps for preventing the pollution of the Clyde. Where the necessary works were voluntarily undertaken by those most immediately interested, the action of the Commissioners would remain chiefly in abeyance. But if the local parties refused or neglected to execute them, the Commissioners should have power either to apply to a court of law to compel their execution, or themselves to execute the works, levying the cost of doing so upon the defaulting authority or owner, and applying to Parliament, when necessary, for the requisite authority.

3. It should be enacted, that 'solid and dry refuse,' not including under that term fæcal matter, should immediately cease to be conveyed or thrown or placed so as to fall or be carried into the Clyde and its tributaries.

4. It should be enacted, that after a definite period, which might be fixed at eighteen months, no fæcal matter or urine from manufactories or public works should, except under special licence from the Sanitary Commissioners, be passed into the Clyde or its tributaries. Within eighteen months it should be practicable, in most cases, to make provision for keeping back these offensive matters.

5. It should be enacted, that after the time absolutely necessary for making suitable provisions to prevent it, no town, village, manufactory, public work, or other premises should in any way pollute the Clyde or its tributaries. What is to be regarded as 'pollution,' I would leave, in the first instance, to be determined by the Sanitary Commissioners, with such technical assistance as they should think fit to employ. But, under sufficient safeguards to prevent vexatious litigation, an appeal might be allowed against their determination to a court of law. The time within which the works for preventing pollution should be executed, and the character of these works, should be decided by the Commissioners.

6. All attempts to lay down satisfactory standards of purity which shall be universally applicable have so signally failed, that I think it worthy of careful trial, whether the question of purity might not be safely left to the determination of a body of persons locally appointed, and, it may be assumed, conversant with the peculiarities and requirements of each district.

7. In some cases the necessary works could not be executed without additional land being procured on which to place them. In these cases, facilities should be given for the compulsory acquisition of the land required, under the provisions of the Lands Clauses Consolidation Acts. As in the case of the Metropolitan Board of Works (18 & 19 Vict. c. 120, sec. 152), it might be provided that these facilities should not be exercised without the previous consent in writing of one of the Principal Secretaries of State.

If an Act of Parliament were obtained giving effect to these general recommendations, I believe the means would at once be available for securing, as far as practicable, the purification of the waters of the Clyde basin. My instructions are limited to that district; but I am bound to say that, if my recommendations are deserving of adoption in regard to the Clyde, somewhat similar provisions should be made in regard to other similarly situated river basins throughout the kingdom. Wherever large populations are

gathered, and numerous manufacturing industries exist on the banks of any river and its tributaries, combined action should, without delay, be taken to secure, as far as practicable, their waters from pollution. As a matter of fairness to manufacturers, all works and manufactories similarly situated should be treated alike. The general provisions I have suggested would ensure this, as far as the region of the Clyde is concerned. If similar provisions were made with regard to other similarly situated river basins throughout the kingdom, it would be necessary that there should be a certain amount of uniformity of action on the part of the different bodies of Commissioners. This might be ensured by the Government appointing an officer who should be *ex officio* member of all the Commissions.

Should the Commissioners fail in the requisite amount of activity and firmness, it would always be open to the Government to take such other steps as might be deemed desirable.

I am assuming throughout this Report that the authorities of the district under consideration, or some large section of it, such as Glasgow, will adopt the initiative by applying to Parliament for the requisite powers to enforce these general provisions. Should they fail to do this, then the interference of Government would be required.

Which I humbly submit to your Majesty.

Witness my hand and seal, this 21st day of March 1876.

JOHN HAWKSHAW. (L. S.)

33 Great George Street, Westminster, S.W.

APPENDIX.

No. I.

ESTIMATE OF WORKS REFERRED TO IN (SIR JOHN HAWKSHAW'S) REPORT.

Length. Miles.	Yards.		£	£
16	836	Intercepting Sewers on the North side of the Clyde, including— 1. High Level Sewer from Airdrie to Shettleston, 2. High Level Sewer from Shettleston to Whiteinch, 3. Low Level Sewer through Glasgow to Whiteinch, 4. Branch Intercepting Sewers for Glasgow and Suburbs, and for Maryhill, Hillhead, etc.,	354,000	
22	440	Intercepting Sewers on the South side of the Clyde, including— 1. High Level Sewer from Rutherglen, with Branch to Pollokshields, 2. Low Level Sewer, with Branch to Renfrew, 3. Intercepting Sewers at Paisley, and Paisley Pumping Station, 4. Intercepting Sewer at Johnstone,	296,000	
38	1276			
		Iron Pipes under the Clyde, and Pumping Station,	150,000	
			800,000	
		Contingencies, 15 per cent.,	120,000	
			920,000	
		Interest on Money during construction,	80,000	
		Cost of the Intercepting Sewers, and of the Pumping Station opposite Whiteinch, including Land,	1,000,000	1,000,000
		The Outfall Sewer,	1,200,000	
		Contingencies, 15 per cent.,	180,000	
			1,380,000	
		Interest on Money during construction,	120,000	
		Cost of the Outfall Sewer, including Land,	1,500,000	1,500,000
				2,500,000

Note.—The cost of the Outfall Sewer would be about the same, whether it terminated at Cloch Point, at Farland Head, or at Irvine Sands.

Annual Charges.

	£
Interest at 4 per cent. on £2,500,000,	100,000
Note.—The rate of interest is taken at 4 per cent. per annum; but if there be a sinking fund, a higher rate of interest would be necessary. On the other hand, the redemption would reduce the capital year by year.	
Annual cost of Pumping,	5,000
Maintenance of Outfall Sewer,	3,000
	108,000

Which sum is about 6½d. per £ on £4,000,000. The present rateable value of the property is about £3,500,000; but before the expenditure for the works can all become a burden, the rateable value of the property will probably amount to £4,000,000.

No. II.

REPORTS to the Metropolitan Board of Works by Sir J. W. Bazalgette and Mr. Keates relative to the Experimental Operations of the Native Guano Company at Crossness.

Engineer's Department, Spring Gardens,
11*th January* 1873.

Gentlemen,—Application having been made to you by the Native Guano Company for permission to erect temporary works on your land at Crossness, in order to enable the Company to submit for your observation the mode of purifying sewage by the A B C process, you sanctioned the experiment on the 27th January 1871, and subsequently directed Mr. Keates and myself to observe and record all the facts bearing upon its operation, and report to you the result. Mr. Keates will report to you the chemical results, whilst I herein submit a statement of the quantities of the ingredients used, the cost of the process (exclusive of buildings, plant, and depreciation, wear and tear), and the commercial results.

The Company's works and operations were in no way interfered with or restricted by your officers, and the Company modified and altered them from time to time according to their own views.

The modifications thus introduced by the Company occasioned considerable delay, and it was not until the 27th August last that they were able to submit their process for our inspection. It was continued from that date up to the 30th November last, or for a period of about three months.

Before reporting to you the results obtained during that period, I should state that I received, on the 10th instant, from Mr. C. Rawson, the general manager of the Company, a letter, bearing date the previous day, addressed to Mr. Keates and myself, urging that certain expenses incurred during the process ought not to be debited to it. But, as his letter had been printed before it was placed in my hands, I assume that it is intended to be read by others as well as Mr. Keates and myself; and whilst I deem it to be my duty to report to you simply what was done, and not what might have been done or left undone by the Company during the three months of the experiment, I must not be considered to assent to the accuracy of the views put forth in Mr. Rawson's letter. It is not for me to say why the Company paid £8, 5s. per ton for sulphate of alumina, if they could have obtained it of equal quality for £2 per ton. Nor did this Board require the settling tanks and machinery to be placed above ground. This was done by the Company for obvious advantages to their works, and had it not been done, other expenses would have been substituted for the pumping now sought to be deducted. There are other arguments in Mr. Rawson's letter to which I should demur; but I proceed to report to you the facts observed.

Between the 27th August and the 30th November 1872, 11,672,737 gallons of sewage were experimented upon, being about 1-343d part of the average flow of sewage discharged at Crossness, and 1-686th part of the sewage of London, and about 2-7ths the quantity proposed to be treated by the Company, who intended to have erected two tanks, each capable of containing 125,000 gallons, by the agency of which they stated they would be enabled daily to effect the conversion into solid sewage matter of the deposit from 500,000 gallons of liquid.

The quantity of A B C mixture used in the shape of alum, clay, charcoal, lime, and blood, amounted to 166 tons, 14 cwt., 1 qr., 13 lbs.; and the sewage treated, assuming it to produce 100 grains to the imperial gallon, 74 tons, 8 cwt., 3 qrs., 16 lbs., making a total of 241 tons, 3 cwt., 1 qr., 1 lb., giving in the shape of dried residue, called Native Guano, 133 tons, 7 cwt., 2 qrs., 11 lbs. Besides this, the subsiding tanks contained, on the 30th of November last, 41·70 tons more of wet mud deposit than they did at the commencement of the trial; this would produce a dried residue of 8·34 tons.

The total expenditure amounts to £895, 3s. 3d., and may be divided thus—

Charcoal (refuse animal),					£63	14	9
„ (wood),					3	12	6
Alum (crude),					175	14	7
Clay alum,					28	18	7½
Clay (common),					18	17	0
Blood,					2	13	0
Coals,					230	11	3½
Lime,					0	6	4½
Wages—							
Manufacturing,	£220	12	2½				
Mechanical supervision,	38	0	10				
Chemical,	33	10	4				
Sale account, bagging and loading,	8	15	3				
Office, wages of boy,	7	16	1½				
					308	14	9
Engine stores,					14	7	4½
Manufacturing stores,					47	13	0
					£895	3	3

This gives the cost of manufacture, taking the dried and wet residue as perfect Native Guano (141·7199 tons), at £6, 6s. 4d. per ton, exclusive of rent, interest on capital, depreciation of plant, and other incidental items.

About 80 tons of the deposit were sent across the river to Messrs. Sillars, who are actively concerned in the management of the A B C Company, to mix with fish manure. Two or three tons of it have been put upon a small quantity of land rented by the Company at Crossness; about 10 tons remain in a wet state, banked up upon the ground; about 40 tons, in a dried state, are in the Company's sheds, and a few tons have been sent away in small quantities as samples; but, with the exception of a few shillings, the Company's books show no returns in the shape of sales of manure.
—I am, gentlemen, your obedient servant,

(Signed) J. W. Bazalgette,
Engineer.

To the Works, etc. Committee of the
Metropolitan Board of Works.

January 13, 1873.

I have the honour to report herewith upon the results of the experimental operations of the Native Guano Company at Crossness, carried on from the 27th August to the 30th of November last, under the supervision of the engineer and myself on behalf of the Board, in accordance with the instructions of the Works, etc. Committee of the 25th July 1871. My report relates, however, only to that part of the experimental working which involves chemical and sanitary considerations; the commercial and financial results are given and treated of by Mr. Bazalgette in his report presented to the Committee at the same time as this.

The experimental works were set partially in operation early in August, and between the 6th and 27th samples of the effluent water were taken on several occasions and submitted to analysis; but before making a definite commencement it was necessary that the stock of materials on the premises should be carefully taken; this was not completed until the 26th of August. On the morning of the 27th, however, at 9 o'clock the works were started, and the experiment effectively begun.

It was intended in the first instance that the operations should be carried on day and night, but consideration showed that it would be very difficult to keep up such supervision as appeared desirable during the night; after discussion it was therefore thought

better by Mr. Bazalgette and myself that the works should only go on during the day, and instructions were given to the effect that working should be commenced at 7 A.M. and be continued up to 5 P.M. daily.

It was also arranged that the work should not be continued on Sundays.

The number of days on which the experiment was actually going on was 80.

To relieve Mr. Houghton from the responsibility of constant attention, and to afford him such assistance as he might require, the Board authorized the sending of Mr. Gotto, one of the officers, to Crossness; from the commencement of the experiment on the 27th of August up to its termination on the 30th of November, he accordingly kept a strict supervision over all the proceedings at the works, day by day, during all the working hours, so that an effectual check was held over all the different operations, and as to materials received on and removed from the premises; he also furnished me with a daily record of the state of the effluent water and of all notable circumstances occurring on the works.

With the object of ascertaining with exactness the current effect of the A B C process upon the sewage, daily samples of the effluent water were taken by Mr. Gotto and my own assistant, and these were analyzed day by day as they were brought up from the works. Samples of raw sewage were also taken on several occasions during the time the experiment was going on, and these were likewise analyzed as they were brought to the laboratory.

The A B C process appears to have been simplified since I inspected the Leamington Works two years ago; at that time a very complex mixture of ingredients was employed, and the mechanical mode of mixing was cumbrous. At Crossness a much simpler formula, containing only sulphate of alumina, clay, and carbon, with a little lime and blood, was employed, and the mixing was effected without mechanical agency by allowing the sewage and A B C mixture to meet as they issued from their respective supply pumps and cistern.

By permission of the Board, the Native Guano Company were to have 500,000 gallons of sewage per day of twenty-four hours; by the reduction of the time of working to ten hours daily, of course this quantity would be reduced in proportion; but, in point of fact, even the reduced quantity was never reached, as the mean quantity treated daily was 145,909 gallons.

The gross quantity of sewage treated during the eighty days of the experiment was 11,672,737 gallons, and to defecate this and precipitate the solid suspended matter with a portion of that dissolved in the sewage, upwards of 166 tons of A B C mixture were employed. This mixture contained the ingredients in the following proportion:—

Sulphate of alumina . .	2.5 parts.
Charcoal	14.5 „
Clay	13.0 „

with a little blood, and occasionally lime.

The carbon and clay, as well as the sulphate of alumina, contained, however, in the state in which they were used, a very large percentage of water, more than 50 per cent., and it is stated by the Company, and my own analyses bear this out, that the 166 tons of A B C mixture, as used, contained actually only about 81 tons of dry material. The amount of dried manure ultimately obtained by treating the 11,672,737 gallons of sewage with the 166 tons of A B C mixture, containing, as I have stated, 81 tons of dry material, was about 142 tons, of which it may be said that about 61 tons were derived from the sewage, and 81 tons added in the A B C mixture.

With reference to the chemical part of the inquiry at Crossness, it appeared to me that there were three principal points for elucidation; these were—

First, as to the effect of the treatment of the sewage by the A B C process as a means of clarification and defecation.

Secondly, as to the possibility of completing the preparation of the manure without creating offensive effluvia, which might prove a nuisance to the surrounding neighbourhood.

Thirdly, as to the value of the manure produced from the precipitated solid matter.

First, as to the effect of the A B C treatment upon the sewage:—

It is to this part of the subject, perhaps, that the greatest importance attaches itself, in a sanitary sense, as upon it depends the solution of the question whether or no the A B C process can so far purify the sewage of towns that it may be allowed to pass into rivers without polluting them to a dangerous degree.

The condition of the effluent water must be taken as the exponent of this purifying action.

The sewage was treated with the A B C material, estimated, in the undried or ordinary state, in the proportion of rather less than 32 lbs. to the 1000 gallons of sewage, and after being thus treated, it passed along through five of the settling tanks, which are 50 feet in length and 20 feet wide, so traversing a distance of about 250 feet, and becoming more and more clarified in its course, owing to the precipitation of the suspended solid matter, which is partly derived from the sewage and partly from the added ingredients. At the end of the last tank, the clarified sewage, or, as it is termed, effluent water, was made to fall over a ledge seven or eight feet high, forming a kind of cascade, into a channel below, by which it was finally carried away into the river. This channel is four feet wide, and upwards of 270 feet long, and its condition during the experiment was the object of constant inspection, as affording an important indication, among others, of the state of the effluent water which flowed through it.

As I have stated before, two samples of effluent water were taken daily during the time the experiment was being carried on; these were taken, one early in the morning, the other in the afternoon. In some cases, both samples were analyzed; but generally the two were mixed, and the analysis made upon the mixed liquid. Altogether, seventy-six samples of effluent water were examined; four between the 6th and 20th of August, and seventy-two between the 27th of August and the end of the experiment on the 30th of November.

In the analysis of effluent water proceeding from treated sewage, there are two determinations which are considered indicative of its character as a possible source of pollution; these are the total solid matter, mineral and organic, dissolved in the liquid, and the amount of organic nitrogen, which represents the putrescible principle.

The quantity of ready formed ammonia contained in such effluent water is of no importance in relation to the question of pollution; in the analyses made of the effluent water from Crossness, the ammonia was, however, estimated. The analytical determinations were, then, the quantity of dissolved solid matter, mineral and organic; the organic nitrogen; the ready formed ammonia; total combined nitrogen; and the amount of chlorine. The quantity of chlorine present is really of no more importance in respect to pollution than ammonia, and it is not registered in the table at the end of this report; but an interesting question having arisen as to the capability of the A B C process to remove a portion of the chloride of sodium present in sewage, I was desirous of settling the point if possible, and I am now convinced, by the results of several experiments, that the quantity of chloride of sodium is not altered by the A B C treatment.

The state of the effluent water at Crossness was, on the whole, extremely good. Occasionally there was a slight smell of sewage at the point where the water left the last settling tank and fell over into the channel by which it finally flowed away, but generally there was little or no perceptible smell, and the water was bright and colourless. On a few days the sewage smell was rather strong in the effluent water, but with those exceptions it was, as I have said, very free from odour, and clear and bright in appearance. As it fell from the tank and flowed along the outlet channel, it was also

free from the characteristic dirty, persistent froth or scum which is generally seen in such cases, and on the occasions of my visits during the experiment, I did not observe any sewage odour over the settling tanks, nor along the course of the channel through which the effluent water was flowing.

For some time after the experiment was begun, the outlet channel was cleaned every morning. On the 10th of September I desired that it should be left untouched, in order that the effect of the effluent water might be noted, and from that date to the end of November, the half of the channel most distant from the outfall at the tank was never cleaned. After ten weeks there was no appearance of sewer fungus or other organic growth on the sides and bottom of the channel.

On several occasions samples of the effluent water were kept in closed vessels in the laboratory, with the object of ascertaining whether it would become foul by the putrefaction of the organic matter which it still contained. It was always found that about the second day the sewer odour became distinct in the water, although not very strong; on the third day, it remained about the same, but after that the odour became less and less in degree, and in a few days was entirely gone. With respect to this point, however, it must be observed, and I shall have again to direct attention to it, that owing to the long-continued rain, the sewage at the southern outfall was abnormally weak throughout the whole of the experiment, and that the putrefactive matter present in it, as measured by the amount of organic nitrogen, was considerably below the usual standard. This, of course, rendered the purification of the sewage by the A B C process much easier than it would otherwise have been, and the results, as exhibited in the character of the effluent water, so far manifest a favourable leaning towards the process.

The analysis of the effluent water bears out the above statements as to its comparative purity, the mean composition of the water, in grains per gallon, during the three months' experiment being as follows:—

Total Solids in Solution.	Mineral Matter.	Organic Matter.	Organic Nitrogen.	Ammonia.	Total Nitrogen.
98.70	88.10	10.60	0.188	1.750	1.938

Secondly, as to the preparation of the dry manure without producing offensive effluvia:—

After the sewage was mixed with the A B C materials it was passed through the length of the subsiding tanks, in which the solid matter was precipitated in the form of thin mud or sludge. The supernatant water was drawn off as closely as possible from the precipitate, which was then pumped up into a peculiar kind of filter known as Needham's Press; by this treatment the mud was brought into the form of a solid cake, still containing, however, about 50 per cent. of water, which had to be in great part removed by subsequent treatment.

Up to the 24th of October there were no means at Crossness of drying the solid material derived from the filters, and an accumulation went on to the extent of between 200 and 300 tons. This mass, which lay for some time in the store, never emitted any offensive smell, although fermentation and considerable heating took place in it.

On the 24th of October a contrivance for drying the solid matter and converting it into manure was completed, and this drying apparatus continued to work, with occasional stoppages on account of mechanical defects, until the end of the experiment.

In drying the precipitated solid matter of sewage, the great difficulty, irrespective of cost, seems to consist in the liability of the animal matter to burn during the process, and so to give off an offensive stench; whilst the drying apparatus was in use at Crossness, however, upwards of 130 tons of manure were dried without producing any offensive emanations.

A further experiment was also made with reference the drying of the mud from the tanks by mere exposure to the action of the air. A space was hollowed out in the ground in the form of a tank, and into this a quantity of the mud was run; the water partly drained away and partly evaporated, leaving the mud progressively more and more consistent. There was no offensive smell developed, although the mud was exposed for sixteen or eighteen days, and was finally dried off at the end of the experiment by the drying cylinder already spoken of.

Thirdly, as to the value of the manure produced by the A B C process:—

With respect to this part of the inquiry, my views are necessarily taken from a chemical standpoint. I have no means of judging of the effects that have been obtained in the practical application of the manure in agriculture, and what I have been able to learn by inquiry seems too vague and conflicting to permit of any satisfactory judgment being formed. Whether or no the fertilizing power of a manure can be exactly measured by its chemical composition, is a question which, perhaps, admits of some discussion; in endeavouring, however, to set a value upon the manure obtained from the working at Crossness, I can only be guided by chemical analysis, giving to the ingredients the understood market value.

The composition of a sample of the manure, as dried in the drying apparatus, and completed ready for sale, is as follows:—

Water, ...	26.45
Organic matter, ...	16.16
Alkaline salts, ...	0.36
Sulphate of lime (traces), .	„ „
Carbonate of lime and magnesia,	2.62
Phosphoric acid, ...	0.48
Alumina and oxide of iron, .	15.42
Insoluble siliceous matter, .	38.51
	100.00

Total nitrogen in the organic matter, calculated as ammonia, 0.929 per cent.

Phosphoric acid, as soluble phosphate of lime, 0.760 per cent.

The ammonia and phosphate of lime are the only substances present in this manure to which any real manurial value can be attached, as the amount of alkaline salts is too low to materially affect the question.

If the value of the ammonia be taken at 7½d. per pound, or £70 per ton, the ammonia contained in a ton of the manure will be worth 15s. 6d. If the phosphoric acid be calculated all as soluble phosphate of lime, and valued at 3d. per pound, or something under £30 per ton, the worth of the phosphate contained in the manure will be 4s. 2d. per ton; adding the value of the ammonia, 15s 6d., to that of the soluble phosphate, 4s. 2d., we have 19s. 8d., say 20s. per ton, as the net value of the manure. Whatever value it may possess beyond this cannot, in my judgment, be estimated upon any chemical reasoning, and I am inclined to believe that continued experience will prove the amount mentioned to be about the fair commercial value of the commodity. I have no means of drawing any inference as to the value of the manure from sales made during the Crossness operations, as, so far as I

am aware, no actual sales, at least of any quantity, of the manure were made.

Taking into consideration the results of the Crossness experiment, chemically considered, I come to the following conclusions :—

First, That the effluent water was, on the whole, very good. The A B C treatment so far clarified and defecated the sewage that, looking solely to the physical condition and chemical composition of the water produced at Crossness, I am of opinion that such water was in a fit state to be admitted into any ordinary river without producing a dangerous degree of pollution. I must here again direct attention, however, to the extremely dilute state of the sewage during the experiment. The effect of this was to render the results somewhat inconclusive, as it is, of course, impossible to say, at least from this experiment, how far the A B C treatment would defecate sewage of a stronger character.

Secondly, That during the preparation of the manure, including the storing of the moist cakes of mud from the presses, and the final drying in the drying cylinder, no offensive effluvia were emitted, and that, taking the experience of Crossness as a guide, the A B C process may be carried on up to the completion of the manure for the market without producing any nuisance.

Thirdly, That the value of the manure, as judged of by its chemical composition, does not exceed twenty shillings per ton.

I beg leave to append a table of all the analyses of the effluent water made during the course of the experiment, commencing the 27th of August, and also of twelve analyses of the raw sewage made at different times during the months of August, September, October, and November. A comparison cannot, however, be drawn between the sewage and effluent water of a corresponding date, as it required some time for the water to pass through the settling tanks. The effluent water of any particular time would, in fact, represent sewage of a time considerably antecedent.

(Signed) T. W. Keates, F.C.S.,
Consulting Chemist, etc.

To the Works, etc. Committee, Metropolitan Board of Works.

Analysis of Effluent Water—Crossness (A B C Process), in Grains per Gallon.

Date, 1872.	Total Solids in Solution.	Mineral Matter.	Organic Matter.	Organic Nitrogen as Ammonia.	Ammonia.	Total Nitrogen as Ammonia.
Aug. 28	90.3	79.8	10.5	0.333	2.205	2.538
„ 29	87.8	78.0	9.8	0.258	2.152	2.410
„ 30	87.9	79.2	8.7	0.297	2.406	2.703
Sept. 2	86.8	78.4	8.4	0.214	1.788	2.002
„ 3	84.8	73.1	11.7	0.200	2.450	2.650
„ 4	81.4	73.2	8.2	0.235	1.680	1.915
„ 5	79.8	69.3	10.5	0.235	1.575	1.810
„ 6	92.4	80.8	11.5	0.298	3.570	3.868
„ 7	81.4	73.2	8.2	0.277	1.662	1.939
„ 10	92.2	81.5	10.6	0.338	2.520	2.858
„ 11	98.8	89.2	9.6	0.238	2.310	2.548
„ 12	115.8	105.0	10.8	0.378	2.450	2.828
„ 16	149.2	133.5	15.7	0.133	2.100	2.233
„ 17	158.5	141.0	17.5	0.280	2.245	2.525
„ 18	158.0	141.0	17.0	0.220	2.310	2.530
„ 19	122.7	116.9	15.8	0.130	1.561	1.691
„ 20	161.7	144.2	17.5	0.343	1.470	1.813
„ 21	168.4	151.2	17.2	0.140	1.561	1.701
„ 23	123.3	112.8	10.5	0.210	2.100	2.310
„ 24	128.1	114.1	14.0	0.220	2.640	2.860
„ 25	124.1	113.6	10.5	0.200	1.750	1.950
„ 26	136.4	123.4	12.9	0.238	1.806	2.044
„ 27	145.9	131.9	14.0	0.360	1.603	1.963
„ 28	113.5	101.3	12.1	...	...	...
„ 30	98.0	86.8	11.2	0.336	2.310	2.646
Oct. 1	110.0	99.0	11.2	...	1.876	...
„ 2	111.7	99.7	11.9	0.280	1.820	2.100
„ 4	93.6	83.4	10.2	0.300	1.456	1.756
„ 5	163.4	149.4	14.0	0.260	2.002	2.262
„ 7	132.3	121.1	11.2	0.198	2.202	2.400
„ 8	105.7	95.2	10.5	0.327	1.617	1.944
„ 9	103.2	93.4	9.8	0.220	1.864	2.084
„ 10	107.4	96.2	11.2	0.378	1.642	2.020
„ 11	98.2	89.2	9.0	0.230	2.401	2.631
„ 12	88.5	78.7	9.8	0.214	1.848	2.062
„ 14	85.7	75.9	9.8	0.265	1.948	2.213
„ 15	92.9	81.3	11.6	0.274	2.100	2.374
„ 16	99.0	88.9	10.1	0.208	2.016	2.224
„ 17	101.5	91.0	10.5	0.292	1.786	2.078

ANALYSIS OF EFFLUENT WATER—CROSSNESS (A B C PROCESS), IN GRAINS PER GALLON—*continued.*

Date, 1872.	Total Solids in Solution.	Mineral Matter.	Organic Matter.	Organic Nitrogen as Ammonia.	Ammonia.	Total Nitrogen as Ammonia.
Oct. 18	108.2	94.5	13.7	0.120	1.260	1.380
„ 19	105.0	100.1	4.9	0.140	1.743	1.883
„ 21	103.9	95.5	8.4	0.214	1.663	1.877
„ 22	100.4	89.9	10.5	0.123	1.997	2.120
„ 23	99.0	89.6	9.4	0.161	1.008	1.169
„ 25	96.6	87.1	9.4	0.120	1.740	1.862
„ 26	82.5	73.5	9.0	0.160	1.645	1.805
„ 28	80.5	70.0	10.5	0.147	1.666	1.813
„ 29	75.2	66.5	8.7	0.252	1.641	1.893
„ 30	87.5	76.6	10.9	0.229	1.643	1.872
„ 31	86.3	76.5	9.8	0.150	1.277	1.427
Nov. 1	63.3	54.6	8.7	0.040	0.906	0.946
„ 2	79.8	69.6	10.2	0.030	0.976	1.006
„ 4	79.4	70.7	8.7	0.036	0.997	1.033
„ 5	76.6	66.8	9.8	0.065	1.386	1.451
„ 6	70.3	61.9	8.4	0.057	1.120	1.177
„ 7	77.8	67.9	9.9	0.046	1.330	1.376
„ 8	82.2	71.7	10.5	0.122	1.428	1.550
„ 12	77.7	67.9	9.8	0.085	1.568	1.653
„ 13	81.5	71.4	10.1	0.067	1.250	1.317
„ 14	82.9	73.8	9.1	0.163	1.489	1.652
„ 15	76.4	69.3	7.1	0.116	1.417	1.533
„ 16	72.1	62.3	9.8	0.202	1.396	1.598
„ 20	75.6	65.8	9.8	0.114	0.837	0.951
„ 21	76.4	67.9	8.5	0.055	1.006	1.061
„ 22	78.9	70.3	8.6	0.066	1.484	1.550
„ 23	80.1	70.3	9.8	0.052	1.008	1.060
„ 27	79.4	70.0	9.4	0.058	1.262	1.320
„ 28	75.2	66.8	8.4	0.110	1.610	1.720
„ 29	78.1	69.0	9.1	0.081	1.302	1.383
„ 30	72.1	63.0	9.1	0.060	1.320	1.380

ANALYSIS OF RAW SEWAGE—CROSSNESS, IN GRAINS PER GALLON.

Date, 1872.	Total Solids in Solution.	Mineral Matter.	Organic Matter.	Organic Nitrogen as Ammonia.	Ammonia.	Total Nitrogen as Ammonia.
Aug. 15	80.5	67.2	13.3	0.700	3.150	3.850
„ 28	74.9	63.7	11.2	0.412	1.621	2.033
Sept. 9	76.6	66.1	10.5	0.294	1.764	2.858
„ 14	77.3	64.7	12.6	0.264	2.597	2.861
Oct. 15	77.0	66.5	10.5	0.382	1.342	1.724
„ 17	87.4	76.5	10.9	0.246	1.260	1.506
„ 23	73.5	66.5	7.0	0.208	1.739	1.947
Nov. 5	61.2	51.7	9.5	0.112	1.300	1.412
„ 16	67.2	56.3	10.8	0.238	1.400	1.638
„ 20	60.6	51.4	9.2	0.145	1.148	1.293
„ 28	63.0	52.5	10.5	0.079	0.940	1.019
„ 30	65.2	53.0	12.2	0.106	1.120	1.226

No. III.

INFORMATION RELATIVE TO WATER SUPPLY OBTAINED FROM

	From what Source is the Water for Domestic Purposes obtained at present?	To whom do the Waterworks belong?	What is the Average and Maximum Volume of Water supplied daily to the District?	Is the present Supply adequate to the requirements of the Town or District?	What is the Rate of Charge for Water?	What have the Waterworks Cost?
GLASGOW.	Loch Katrine and the Gorbals Gravitation Waterworks.	To the Glasgow Corporation Waterworks Commissioners.	Galls. a day. Average, . . 35,000,000 Maximum, . . 38,500,000	Yes.	Domestic rate within Municipality, 8d. a £; domestic rate beyond Municipality, 11d. a £; public rate within Municipality, 1d. a £.	£1,755,414.
PAISLEY AND JOHNSTONE.	Harelaw, Stanley, and Rowbank Reservoirs.	To the Corporation of Paisley.	Galls. a day. Average, . . . 3,116,000 Maximum, ...	Yes.	Domestic rate, 1s. a £; public rate, 1d. a £.	Old works, . . . £60,000 New works, . . . 77,348 Total, . . . £137,348
PORT GLASGOW.	The Gryfe Water and Finlayston Burn.	To the Police Commissioners of Port Glasgow.	Galls. a day. Average, . . 408,000 Maximum, . . 442,000	Yes.	Water rate, 1s. a £.	£16,975.
DUMBARTON.	Overton Burn.	To the Town Council of Dumbarton.	Galls. a day. Average, . . 340,000 Maximum, . . ,,	Yes.	Domestic rate, 6d. a £; public rate, 6d. a £; for trade purposes, £2 10s. per 100,000 gallons.	About £20,000.
DUNTOCHER AND DALMUIR.	Cochno Loch.	The Local Authority of the Parish of Duntocher.	Works not yet quite complete.	...	Water rate, 1s. a £, partly on tenants and partly on proprietors.	About £10,500.
KIRKINTILLOCH AND LENZIE.	Corrie Spout and other streams near Drumairn.	To the Local Authority of the Parish of Kirkintilloch.	Galls. a day. Average about . 100,000	Yes.	Water rate, 1s. 3d. a £.	About £14,500.
AIRDRIE AND COATBRIDGE.	Roughrigg Reservoir and Shotts Burn.	Partly to the Caledonian Railway Company, and partly to the Airdrie and Coatbridge Water Company.	Before the 11th April 1875, the quantity was about 1,750,000 gallons a day. Now it is largely increased, and estimated at 2,500,000 gallons a day.	Yes.	Water rate, 1s. a £, and by meter 50s. to 30s. per 100,000 gallons, according to quantity consumed per half year.	Works have cost . . £36,807 Expected to be paid to Caledonian Rail. Co., . 17,425 Add for new piping, . 15,000 Approximate cost, . £69,232
MOTHERWELL.	River Clyde.	To the Commissioners of the Burgh of Motherwell. Water pumped by the Caledonian Railway Company.	Quantity supplied to Burgh of Motherwell, 58,000 gallons a day.	No.	No special assessment.	The Burgh pays £100 per annum to the Caledonian Railway Company. Cost of piping not ascertained.
WISHAW.	Bouridge Burn, Gair Burn, and certain springs near the latter.	To the Commissioners of the Burgh of Wishaw.	The daily consumption is from 210,000 to 215,000 gallons a day. Exact average and maximum not known.	Yes.	No special water rate; but included in 1s. 6d. a £ for all purposes. By meter, 50s. per 100,000 galls., and in a few cases 70s. per 100,000 galls.	With the exception of some old piping, the works have cost about £7,000.
LANARK.	Springs near Lanark Moor Loch, a small stream, and about 12 pump wells in various parts of the town.	To the Town Council of Lanark.	Not known; but thought to average about 60,000 gallons a day.	Said not to be quite sufficient.	There is no water rate; but a few consumers pay a voluntary annual subscription.	Cost of works not known.
HAMILTON.	Earnock Burn.	The Hamilton Waterworks Commissioners.	Galls. a day. Average, . . 200,000 Maximum, . . 225,000	Yes; but works are about to be extended.	Public rate, 5d. a £; domestic rate, 6d. a £; by meter, 35s. per 100,000 gls., when public rate is also charged.	About £15,000.
CAMBUSLANG.	Turnlaw Reservoir.	The Local Authority of the Parish of Cambuslang.	Present consumption stated at 46,653 galls. a day. Works about to be constructed are expected to supply 190,000 galls. a day.	When new works are completed, they will be adequate.	Rates of charge for water—Lands and heritages, 6d. a £; houses, 1s. a £; minerals, 3d. a £.	About £3,000.

No. IV.

INFORMATION REGARDING EXISTING WATERWORKS.

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1. AIRDRIE AND COATBRIDGE WATERWORKS.

Area of District supplied, ... about 1500 Acres.

	Area of Gathering Ground.	Area.	Capacity.
	Acres.	Acres.	Gallons.
Reservoir, . . .	750	116	468,750,000
Shotts Burn (where the Tunnel enters), . .	1600	...	...
	2350	116	468,750,000

Area of Filters, ... 2,500 Square Yards.
Capacity of Tank, ... 580,000 Gallons.

2. CAMBUSLANG WATERWORKS.

Area of District supplied, ... 380 Acres.

	Area of Gathering Ground.	Area.			Capacity.
	Acres.	Acres.	Roods.	Poles.	Gallons.
Lower Reservoir, . .	80	3	1	0	3,200,000
Higher do., . .	147	9	3	27	16,283,000
	227	13	0	27	19,483,000

Area of Filters, ... 320 Square Yards.
Capacity of Tank, ... 47,700 Gallons.

3. DUMBARTON WATERWORKS.

Area of District supplied—

	Acres.	
West of River Leven, ...	215	= 665 Acres.
East of do., ...	450	

	Area of Gathering Ground.	Area.			Capacity.
	Acres.	Acres.	Roods.	Poles.	Gallons.
Garshake Reservoir, .	619	4	0	38	14,686,406
Black Linn do., .	111	10	1	0	21,875,000
	730	14	1	38	36,561,406

Area of Filters, ... 400 Square Yards.
Capacity of Tank, ... 125,000 Gallons.

4. DUNTOCHER AND DALMUIR WATERWORKS.

Area of District supplied, ... 2600 Acres.

	Area of Gathering Ground.	Area.			Capacity.
	Acres.	Acres.	Roods.	Poles.	Gallons.
Cochno Loch, . .	361	38	2	0	251,000,000
		When Raised.			
		62	3	0	

5. GLASGOW WATERWORKS.

Area of District supplied—

	In Mass Acres.	Detached Acres.	Total Area.
North of Clyde and East of Kelvin, ...	4965	662	...
Do. and West of do., ...	548	658	...
South of Clyde, ...	1553	2104	...
	7066	3424	10,490 Acres.

Note.—Each pipe along a suburban road is supposed to supply an area 500 feet wide.

(1.) Portion within the Region of the Clyde, as shown on Plan No. 2.

(*a*) *Gorbals Waterworks.*

	Area of Gathering Ground.	Area.			Capacity.
	Acres.	Acres.	Roods.	Poles.	Gallons.
Balgray Reservoir, .	2560	153	2	6	746,826,662
Royal Linn do., .		21	0	15	74,852,431
Waulkmill Glen do., .		47	3	4	288,383,187
Littleston do., .		4	0	22	8,458,550
	2560	226	2	7	1,118,520,830

Area of Filters (Waulkmill Reservoir), ... 3832 Square Yards.

	Gallons.	
Capacity of Tank (Balgray Reservoir), ...	200,000	= 3,436,100 Gallons.
Do. do. (Waulkmill do.), ...	3,236,100	

(*b*) *Mugdock Service Reservoir, in connection with Loch Katrine Waterworks.*

	Area.			Capacity.
	Acres.	Roods.	Poles.	Gallons.
Main Reservoir, . .	59	3	3	548,655,565
Upper Pool, . .	1	3	38	5,256,725
. . . .	61	3	1	553,912,290

(2.) Portion without the region of the Clyde, as shown on Plan No. 2.

Loch Katrine Waterworks.

	Area of Gathering Ground.	Area.			Capacity.
	Acres.	Acres.	Roods.	Poles.	Gallons.
Loch Katrine, . .	23,192	3058	2	38	5,623,581,250
Loch Vennachar, . .	24,686	1021	2	20	2,588,960,350
Loch Drunkie, . .		148	0	16	773,750,063
	47,878	4228	1	34	8,986,291,663

6. GREENOCK WATERWORKS.

Area of District supplied, ... 2230 Acres.

(1.) Portion within the region of the Clyde, as shown on Plan No. 2.

Maximum Supply to Town from Gryfe, ... 6,280,416 Gallons per day.
Average „ „ . . . . . 4,079,160 „

	Area of Gathering Ground.	Area.			Capacity.
	Acres.	Acres.	Roods.	Poles.	Gallons.
No. 1 Reservoir, . .	1,622	166	3	11	903,000,000
No. 2 Reservoir, . .	791	70	2	24	431,000,000
	2,413	237	1	35	1,334,000,000

(2.) Portion without the region of the Clyde, as shown on Plan No. 2.

Supply to Town—
To Public Works by Meter, ... 1,524,333 Gallons per day.
To Inhabitants, ... 4,449,985 „
5,974,318 „

	Area of Gathering Ground.	Acres.			Capacity.
	Acres.	Acres.	Roods.	Poles.	Gallons.
Kelly Reservoir, . .	744	10	1	14	38,987,000
Crawhin Reservoir, .	212	10	1	10	18,125,000
Kelly Aqueduct, . .	574		...		...
Compensation Reservoir,	344	40	2	0	90,412,000
Loch Thom, . .	3,600	296	2	35	1,779,241,000
Main Aqueduct, . .	675		...		...
Reservoirs 2 & 4, .	33		...		19,000,000
Reservoirs 1, 3, 5, 6, & 7,	489		...		70,858,000
Filter Aqueduct, . .	94		...		...
Overton Reservoir (at end of Main Aqueduct),	...	2	0	2	2,178,000
Whinhill Reservoir, .	420	16	1	37	59,556,000
Cowdenknowes Reservoir,	129	7	1	38	21,164,000
Town's Reservoir, .		1	3	8	6,928,000
Berry Yards Reservoir,	52	0	2	16	1,892,000
Total,	7,366	...			2,108,341,000

	Area. Square Yards.		Capacity. Gallons.
High Filters, .	5,666	High Tank, .	3,271,000
Low „ .	887	Low „ .	500,000
	6,553		3,771,000

7. HAMILTON WATERWORKS.

Area of District supplied, ... 594 Acres.

Area of Gathering Ground.	Area of Reservoir.			Capacity of Reservoir.
Acres.	Acres.	Roods.	Poles.	Gallons.
370	15	2	0	50,000,000

Area of Filters, ... 577 Square Yards.
Capacity of Tank, ... 98,000 Gallons.

8. KIRKINTILLOCH and LENZIE WATERWORKS.

Area of District supplied—

	Acres.	
Kirkintilloch Water Supply District, ...	330	= 604 Acres.
Lenzie ditto, ...	127	
Supply beyond Municipal Boundaries, ...	147	

Area of Gathering Ground, ... 386 Acres.
There are no Reservoirs.
Capacity of Tank, ... 200,000 Gallons.

9. LANARK WATERWORKS.

Area of District supplied, ... 85 Acres.
Capacity of Tank, ... 159,750 Gallons.

Note.—The water supply is obtained from springs.

10. MOTHERWELL WATERWORKS.

Area of District supplied, ... 214 Acres.
Capacity of Caledonian Railway Company's Reservoir, ... 1,273,600 Gallons.
Area of Filter, ... 89 Square Yards.
Capacity of Tank, ... 22,500 Gallons.

Note.—The water supply is obtained from the Clyde.

11. PAISLEY WATERWORKS.

Area of District supplied—

	Acres.	
Within limits of compulsory supply to Paisley, ...	3540	= 4049 Acres.
„ „ Johnstone, ...	138	
Outside limits of compulsory supply to Paisley, ...	254	
„ „ Johnstone, ...	117	

	Area of Gathering Ground.	Capacity.
	Acres.	Gallons.
Harelow Reservoir, .	166	89,050,000
Stanely „ . .	624	177,125,000
Clear Water Basin, .	...	44,962,500
Rowbank Reservoir, .	1220	481,250,000
	2010	792,387,500

Area of Filters, ... 3,120 Square Yards.
Capacity of Tank, ... 1,564,475 Gallons.

12. PORT GLASGOW WATERWORKS.

Area of District supplied, ... 500 Acres.

	Area of Gathering Ground.			Area of Impounding Reservoir.	Capacity of Impounding Reservoir.
	Acres.	Roods.	Poles.	Acres.	Gallons.
From Gryfe, . . .	162	2	0	...	...
From Finlayston Burn,	62	2	0	...	...
	225	0	0	21.75	56,250,000

13. WISHAW WATERWORKS.

Area of District supplied, ... 407 Acres.

	Area of Gathering Ground.	Capacity.
	Acres.	Gallons.
Upper Reservoir, . .	255	12,000,000
Under „ . .	142	2,000,000
	397	14,000,000

Area of Filter, ... 196 Square Yards.
Capacity of Tank, ... 118,800 Gallons.

MINUTES OF EVIDENCE.

MINUTES OF EVIDENCE

TAKEN BEFORE

THE COMMISSIONER

APPOINTED TO INQUIRE INTO

THE BEST MEANS OF SECURING THE PURIFICATION OF THE RIVER CLYDE AND ITS TRIBUTARIES.

GLASGOW, MONDAY, 17*th May* 1875.

Present:

SIR JOHN HAWKSHAW.

THE *Commissioner* stated that the intention to hold a public inquiry had been advertised in all the districts interested in the purification of the Clyde and its tributaries, and he was now ready to receive any evidence which might be tendered as to the best means for securing that object.

Mr. ALEXANDER GEORGE THOMSON, C.E., Glasgow, examined.

Alex. George Thomson, C.E.

1. The witness read and put in the following statement:—

'194 WEST GEORGE STREET, GLASGOW,
13*th May* 1875.

'To Sir John Hawkshaw, Mem. Inst. C.E., H.M. Commissioner for promoting the purification of the river Clyde.

'SIR,—I am a civil engineer of a good many years' standing in Glasgow, and have always been greatly impressed with the importance of arriving at a satisfactory solution of the problem of the disposal of the sewage of this great city.

'Understanding that you are now holding a local court of inquiry, I think I cannot do better than submit for your consideration such views as I have formed on this subject, and which, I may state, I have not hitherto made public in any shape.

'The scheme is briefly as follows:—

'(1.) I am not of opinion that to convey the sewage to a considerable distance and discharge it at a lower point of the river or estuary would be a satisfactory solution, as that would involve the contamination of other localities for the benefit of Glasgow.

'(2.) It is perfectly practicable, in the present position of chemical and engineering science, to purify the sewage in the immediate vicinity of the city, with an apparatus so substantially constructed and well ventilated as to obviate any inconvenience.

'(3.) The sewage of Glasgow is so charged with refuse of public works as to render its utilization a matter of secondary importance.

'(4.) Starting from these premises, I would propose to reduce the quantity of matter, *first*, by keeping the rainfall separate from the sewage, and carrying it off by a new set of drain pipes; and, *secondly*, by enacting that all W.C.'s be provided with apparatus for restricting the quantity of water used for flushing.

'(5.) The sewage thus reduced in quantity would be conveyed through existing sewers to a northern and a southern *intercepting sewer* of moderate dimensions, constructed with sufficient fall from the centre eastwards and westwards; an overflow sluice to river being provided for use in case of repairs.

'(6.) Intercepting sewers to terminate at each end in air and water tight *receivers*, surmounted by lofty and capacious *cupolas*, gathering into a ventilating shaft or lantern in the upper part. These cupolas, being prominent objects, should be architecturally treated and varied in design.

'The sewers also to be connected with ventilation shaft at intermediate points.

'(7.) The gaseous products arising from the sewage to traverse ashpits of furnaces placed at the base of the ventilating shaft, by which means they would be partially consumed, and the ventilation rendered more powerful.

'(8.) Layers of common gypsum (sulphate of lime) should be deposited within the shafts to fix the volatilized carbonate of ammonia, which is one of the chief products arising from sewage, and convert it into ammoniacal salts, which are innocuous and of some value.

'(9.) The remainder of the sewage matter I propose to treat by a process of calcination or cremation, as follows:—Benches of retorts are to be arranged in ovens, in sufficient numbers, around the base of the receivers.

'These retorts are in the first instance to be charged with a proportion of sodium, or such other chemicals as shall by their affinity for the water of the sewage decompose it, seize its oxygen, and in so doing cause the hydrogen, sulphur, phosphorus, and all combustible constituents to burn, leaving a remnant of calcined ashes, containing a proportion of potash and silica, to be periodically removed, and of some value as manure. The application of heat will expedite the process.

'The charging of the retorts with the sewage matter to be effected by mechanical means.

'(10.) The plan here proposed can be carried out by degrees, and a portion of the larger existing sewers could probably be made available as intercepting sewers. Its application to localities deficient in a suitable outlet for liquid sewage is particularly obvious.

'I will only add that I should be happy to be permitted to co-operate in the great work committed to your charge, whatever means may be resolved upon for its accomplishment.

'I am, Sir, your obedient Servant,
'ALEX. GEORGE THOMSON, C.E.'

2. You have not attempted to form any estimate of the cost of this scheme?—No; I have not gone into details. I should imagine, however, that the products remaining might compensate for the cost of the chemicals used.

3. Have you considered the difficulty there would be in keeping your drains open, while excluding the rainfall from them entirely?—We have such an abundant supply of water for flushing, that we are not dependent upon the rainfall here for that purpose.

4. Then you propose to use water for flushing these sewage pipes or drains?—There are certain patents

Alex. George Thomson, C.E.

which have, I think, given satisfactory results for limiting the quantity of water used, and preventing waste. There is a great deal of water wasted in the closets here.

5. You propose by your scheme, that what may be called the sewage drains should take everything from the houses except the rainfall; I mean should take slops and all the refuse from the houses, simply excluding the rainfall?—That is so; and I propose that simply for the reason that the rainfall will not pollute the river when poured into it, and it is a very variable quantity.

6. But how would you deal with the washings from the streets? Would they go into your rainfall sewers?—They would go into the rainfall, undoubtedly.

7. Then you would still put a considerable amount of pollution from the streets into the river? If you were to allow the washings of the streets to go with the rainfall, you would not then have unpolluted water to deliver into the river?—No. I don't think, however, that the washings of the streets would produce such a pernicious effect as the products from the various water-closets and public works.

8. Have you made any calculation of the quantity of sewage that you would have to deal with in this manner, supposing you had separated it from the rainfall?—The present quantity of sewage, exclusive of rainfall, is about 35,000,000 of gallons daily; but that quantity might be considerably reduced by the use of some of the patents, such as Hoey's patent, which have been introduced to avoid waste of flushing water.

9. Have you estimated, or tried to estimate, the proportions in that 35,000,000 gallons of solid and liquid matter when you were considering the question?—No. I have not attempted to calculate that, but I believe the water used is perhaps twice as much as is at all necessary.

10. I don't quite see from your statement, in what way you propose to deal with the liquid part of the sewage?—The liquid is reduced to a minimum, and it would be treated in the retorts as I propose.

11. Yes, but I don't quite see how you would deal with the liquid in retorts. How would you get the liquid into the retorts?—Of course, to some extent, there would be evaporation; and the matter remaining after the flushing water is reduced to a minimum would probably be of a nearly solid character.

12. Then if you got it of a solid character, I don't see how it would flow through your drains. You must keep it liquid to get it to flow to these establishments. If you make it solid before it starts towards these establishments, it would not flow at all. It would simply remain, and fill up the drains?—I believe it would be worth while to try the process on a section of drainage in the first instance. Hitherto the process chiefly used has been simply filtration; and this would be a different method, which might be found to remove some of the inconveniences of simple filtration, and make the purification more thorough. It does not necessarily exclude filtration; it might be a good supplement to it.

13. Have you got any calculation as to the amount of rainfall? You have given me 35,000,000 gallons daily as the amount of sewage. Have you estimated the rainfall at any quantity in your calculation?—It is an exceedingly variable element. I think the rainfall alone varies from 35,000,000 gallons daily to about double that.

14. You are speaking now of Glasgow, I suppose?—Yes.

15. Can you tell me, when you speak of Glasgow, what area you take in, because that is rather an indefinite term?—I would take in the present boundaries.

16. Do you know the acreage of that?—No.

17. But you deal with the present boundaries of the city, I suppose?—Yes; I don't refer to the suburbs, because this process would probably require to be applied there at different intervals, at the extremes, as the suburbs are continually extending.

18. Do you take the Parliamentary boundary of the city of Glasgow into your calculation?—The limit I was supposing was the Kelvin.

19. Is there anything more you would like to add to the statement you have made?—The only point is one to which I have already referred,—that I would not consider this process to exclude filtration.

20. You mean that it would include it?—Yes. I mean that filtration could be applied with advantage in conjunction with it.

Mr. Malcolm M'Callum, 8 Scotia Street, Glasgow, examined.

21. What are you by profession?—I am at present out of business. I have been connected with building, very much as an amusement, for many years.

22. The letters, of which I have been furnished with a copy, written by 'A Builder' were written by you?—They were.

23. I have seen a copy of these letters before; but I did not know the author. I have read the letter which describes what you propose; but you will perhaps now state it more in detail?—I have simply attended here in order that you might have an opportunity, after perusal of the letter, of putting any questions to me that might suggest themselves to you.

24. I see that what you propose is to pass the sewage into an improved cesspool, which you describe very clearly in your letter?—Yes. The process may be described as filtration, with the preservation of the refuse.

25. The plan is simple enough,—I mean your description of it is quite clear; and I quite understand your proposal, which is in reality to make improved cesspools into which you pass the sewage, and purify it in the cesspool?—Yes, and to allow the water to escape to the running streams comparatively pure,—in fact, absolutely pure. I may mention that when Messrs. Bateman & Bazalgette were in town, some three or four years ago, I had an interview with them, and they made a very fair reference indeed to my pamphlet in their final report,—as fair a reference as I could have looked for, seeing they had a proposal of their own.

26. Your plan seems to me to be rather an extension of what is called the earth-closet system, except that you propose that ashes should be used instead of earth?—Quite so. In fact, the normal refuse of a domestic establishment might be a sufficient agent, and, of course, it is entirely outside of any premises.

27. But what would you do with the mills and manufactories, and other public works?—These would require a special adaptation of the system. Of course the view of it taken in these letters is only applicable to dwelling-houses; but a modification of it might be so arranged as to suit almost any conceivable circumstances.

28. Do you consider that these ashpits of yours would be applicable to mills and dye works and paper works?—Yes. It would of course be a *sine qua non* that the whole of these closets should be several feet, or at least feet, above the ordinary level of the outer ground,—gravitation being the power employed.

29. Are there at present in Glasgow any large number of cesspools?—No. I am not aware that any system of cesspools has ever been adopted in Glasgow It is not in favour with the Scotch public.

30. They are extensively adopted in Manchester?—They are; but the ordinary water-closet, with all its objections, is certainly preferable to cesspools.

31. Do you suppose that, taking the densely-crowded portions of Glasgow, there would be enough ashes made in the houses there to purify the sewage in the way you propose?—Yes; I think so.

32. Do they all burn a sufficient quantity of coal for that purpose?—I think so, if you take into account the sweepings and the natural refuse from every establishment—waste paper, straw, and all the odds and ends that constitute the contents of an ordinary ashpit.

33. Only, in order to purify the sewage effectually, you want ashes, if you can get them?—Yes; but if

the quantity was short, it would be a very simple matter to supplement it with a little earth. I believe it is pretty well understood and admitted that there can be no better deodorizer than ashes.

34. Take the summer season, for instance. Would you then have a sufficient number of fires going in districts covered with cottage property to give you ashes enough?—We have always fires in use, both summer and winter, in kitchens.

35. I am alluding now to a working population. Of course I don't profess to know enough about it myself to be able to tell; but I am only asking whether in summer you think it is probable that a sufficient quantity of ashes would be made in that class of houses to answer the purpose which you are aiming at by your proposal?—Yes. I think the ashes and the other natural refuse of every domestic establishment would about provide enough for the purpose; but as I have said, if the quantity was short, it might very easily be supplemented by a little earth.

36. But if you had to find ashes somewhere else, and cart them to these pits, and put them in, then you would have the same difficulty that you have in the extensive application of the earth-closets?—I don't anticipate that there would be found to be any scarcity. In two distinct cases I put that plan into operation, and I found it to be most effective.

37. There is no doubt that ashes would be as effective as dry earth, but I am rather directing my questions to the possibility of having a sufficient quantity of ashes in densely-populated districts to allow of such a purification as you seem to expect from your system?—We use coals so bountifully and so freely in Glasgow, in consequence of their comparatively low price, that I do not anticipate there would be any difficulty at all on that score. As I have said, I found it in two instances to be thoroughly effective.

38. I quite understand that it would be effective if fairly carried out in situations where you could apply it and look after it,—I mean that it would no doubt act the same as the earth-closet acts, which deodorizes the sewage; but it would not do to depend upon any kind of rubbish being thrown into these cesspools, because if you begin to throw vegetable matter, such as cabbage leaves and things of that kind into them, you would produce an evil instead of a benefit?—I don't know that any evil would be produced by the mode which I have described.

39. Not by the mode, but it is the difficulty of effectually carrying out the mode which I am dealing with. I mean it would not do to replace ashes with vegetable matter, and so on, because then you would get putrefaction?—The stuff would then be better fitted for agricultural purposes, and then the places could be cleansed out, possibly at an interval of a very few days.

40. Would you propose to make these places of such a size that they would require cleansing say once a week?—That might be rather too often; but possibly two or three weeks' supply would justify removal. I don't by any means offer this as a perfect scheme. There is no doubt each position of property would require certain modifications. I offer it simply as the rudiments of what has long appeared to me to be a practical solution of the question.

41. Don't you think you have rather under-estimated the expense?—I do not.

42. In some places you would have a difficulty in finding space, I should think?—Yes; but I suppose that in nine cases out of ten there are already spaces allotted for these purposes.

43. Do you propose a cesspool for each house?—No; but I think the term 'cesspool' is altogether inapplicable.

44. Then do you propose one place, whatever you call them, for a group of houses?—I would propose one for each tenement, as we call them in Scotland; not for each dwelling, but for each separate building.

45. What do you call a tenement?—A 'land' possibly of four flats, having perhaps eight or ten houses, one above the other, but all under the same roof. There is generally an ashpit attached to each tenement, and that ashpit would be appropriated as a filter for the water-closet sewage which would be discharged into it. That may be said to be the germ of the idea.

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46. Have you any idea of the number of tenements in Glasgow?—No. I am not prepared to speak upon that point, but I daresay an approximation to it could be got in a very few minutes.

47. Of course you would require a separate drain from each ashpit to the sewer?—Yes; but there is nothing more simple than that, and the mode in which it is carried into effect is, I think, clearly pointed out.

48. Do you propose that these places should be all emptied at night?—Surely. That is the plan presently followed in Glasgow,—to empty the ashpits at night, and, of course, it is the only proper plan.

49. Do you propose that all the slops from every tenement should be emptied into this receptacle?—Yes. I think that would be an improvement, and I would recommend that.

50. Don't you think it is possible that you would have these places overwhelmed sometimes, and that you would not get room for all the sewage?—I don't think so. We know that there are a great many valuable fertilizing agents contained in these fluids.

51. There is no doubt about that; but I mean, looking to the chance of the progress of this large quantity of fluid being stopped, and not getting to the bottom of the chamber which you propose?—I think that, with ordinary care in the preparation of these filters, there would be no chance of a stoppage; but even if there were, the construction of it is such that a very few hours would put it right. Of course, as I have already said, I do not by any means recommend this as a thorough, efficient plan; and I have entered a caveat in a preliminary note that each position of property must be regulated by rules applicable to itself.

52. Is there anything more you would like to explain?—No. I would leave the pamphlet to speak for itself; but I thought it proper to attend in case the perusal of it might suggest any questions to you which you might desire to put.

53. The explanation of your plan is clear enough, and I quite understand it. The only questions which have suggested themselves to me I have already put, namely, as to the possibility of the liquid not making its way with sufficient rapidity through ashes, especially if they happen to be fine ashes?—With the slightest attention to workmanship there would be no structural obstacle that could possibly arise.

54. Then there is just the other question, as to whether or not the bottom chamber which you propose to make might not fill up in the course of time, and have to be taken out?—It is quite a possible, but it is an unlikely thing. However, from the construction of it, that would be a matter that could be put right in a few hours.

55. Is there any particular limitation as to the depth of ashes that you would propose to use?—No.

56. I see you give a depth for the pit. Of course if your ashes were of any great depth, the liquid would go through them very slowly, and nothing stops the progress of liquid so much as very fine ashes; we use them sometimes to stop the percolation of water?—So long as the water went away freely, I would have no limitation to it.

57. But I am looking to the possibility rather of its not going away freely, and that would depend upon two things—first, the depth of the bed of ashes, and, second, the fineness of the ashes?—I have known the depth in such an ashpit as is there described to amount to 3 or 4 feet, and yet the water escaped perfectly freely. Of course it would not be advisable to have a greater depth than that, nor could there possibly be a greater depth if there was cleansing within one or two weeks.

58. There have been cases within my own knowledge where drains have had to be taken up because they were found to be choked or stopped up with ashes. I have had some cases of that kind in matters on which I have been engaged before.—I have no doubt that, with the sand or gravel which would divide the small

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flags described, there could be no escape of the dust or ashes into the drain. In fact, there is nothing that can intercept ashes more thoroughly than a bed of sand, or coarse sand and small gravel.

John Carrick.

Mr. JOHN CARRICK, Master of Works, Glasgow, examined.

59. As you are aware, Sir John, the subject of your inquiry has engaged the attention of the Town Council of Glasgow for many years, and I think it would perhaps be convenient now that I should put in the reports which the Town Council have received upon that subject from time to time. The first is a report on the sewerage of Glasgow, addressed to the committee of the Town Council of Glasgow, by Mr. John Frederick Bateman, dated 1st December 1858, and it has reference to various experiments that were made upon Pinkston Burn with the view of ascertaining the value of treating the sewage of Glasgow by precipitation. Following upon that, there is also a report upon the same subject by the late Professor Anderson, Professor of Chemistry in the University of Glasgow, and Mr. Bateman, to which there is an appendix, containing the report of the experiments that were carried on at the Pinkston Burn under the superintendence of Mr. Napier.

60. What is the date of that?—July 1858. These two reports contain full information as to our experience of the various means adopted for deodorizing the sewage of Glasgow. I also beg to submit to you the report by Messrs. Bateman & Bazalgette, of date 20th July 1868, on the subject of the sewerage of Glasgow and the purification of the river Clyde. That report contains very ample information upon all the various schemes that up to that date had been considered for the purification of the river, and it is accompanied by plans and various information which, I have no doubt, will be useful. I deem it unnecessary that I should give any explanation about that, as the report speaks for itself. Following upon that is a separate report by Professor Anderson upon the chemical view of the matter. I think these reports contain all the reliable information that we have upon the subject up to date. The Town Council have had, from time to time, numerous schemes laid before them for the accomplishment of the objects aimed at, but not assuming any definite shape. I believe you will have the parties themselves before you to advocate their various schemes; and I may perhaps direct your attention before you leave to a limited project which I myself submitted to the Town Council on the same subject, but I think this is the best time to give you the formal information which I have now laid before you.

TUESDAY, 18*th May* 1875.

David Falconer.

Mr. DAVID FALCONER, Joiner and Inspector of Works, 3 Pitt Street, Glasgow, examined.

61. *Sir John Hawkshaw.*—You exhibit a model which you propose to apply for the purification of sewage?—Yes.

62. Can you shortly explain how that model is intended to work?—The sewage is supposed to go in by this entrance (showing) and go through this extractor (showing), and then to go down into the well here (showing) through the sieves, and then to go down into this place (showing) below the river bottom, and it comes up through this grating (showing) to the river again; sometimes these parts of the machine (showing) require to be turned in order to get rid of any glut, and to keep everything clear.

63. You let the sewage in through this pipe (showing) to what you call an extractor, which is supposed to revolve inside, and which is to be perforated, I understand, with holes?—Yes.

64. The sewage, having passed through that, goes down through the strainer to the bottom of the river, and then rises up through a grating into the river?—Yes.

65. I suppose you would propose to clean out the apparatus frequently?—Yes; it would be cleaned out every time it was needed. The model is supposed to represent an apparatus 16 feet square, and then, of course, there would be an apparatus above for the purpose of burning the gas, but it was too large to bring here. It is for the purpose of burning the gas above, but it is such a common thing that the way of carrying it out is quite well known to engineers. This piece of the apparatus (showing on model) is for the purpose of taking off any grease or floating matter that comes in.

66. You mean that it is for taking off the scum?—Yes. I may say that I have been observing the river for more than forty years, ever since we had a severe touch of cholera here, and when we all had 'middens,' and places of that kind, at the backs of our houses, and dry water-closets. I began to pay attention to the subject then, and I have since given it a good deal of consideration. I may also say that I have some other things on hand for raising the air and the water and the gases, but I did not think it necessary to bring them here.

67. Have you tried this apparatus of yours at all? Have you made any experiments in order to see how it would work?—I have made no further experiments than in my own house.

68. But have you made experiments anywhere?—Yes; but just in the jawbox of the house. I had no means of doing anything else. The jawbox is a place in the kitchen, which would be called a sink, for putting in the house refuse.

69. You have tried your apparatus there?—Yes. I have tried it there on my own account.

70. And you have tried it nowhere else?—No.

71. Then, of course, you can give me no information as to the power which such an apparatus would require if it was made 16 feet square?—The extractor would require a good deal of power to drive it, but not a very great deal either, because the water, while it runs in at the one side, would be made to run out at the other side.

72. What do you expect to gain by the use of the extractor? The sewage after it passes through the extractor goes through the strainer, and I don't quite see the value of the extractor. What is the object of it?—It is for taking the gases out.

73. Then you seem to think that by making the extractor revolve rapidly the gases will escape?—They will escape quite furiously; indeed, you could hardly stand beside it while the water was going into the extractor without covering up your mouth and nose. If you were standing at the side of one of them, even in a common washing-house, where they were washing, and using the extractor for taking out the soap and ashes and soda, and other things of that kind from the clothes, you could hardly stand near it in consequence of the speed at which the extractor would be going.

74. Then the use of the extractor is for the purpose of making the gases separate from the sewage?—Yes; to separate them from the sewage, so that they may get speedily away to be burned or consumed, or carried off through the vent.

75. Then I understand you propose that a boat is to come alongside of this apparatus, and to take away the solid matter?—Yes, if the apparatus is put into a place that is suitable for that purpose, and where the solid matter has to be taken away while the tide is out; but when the tide is up it rises to the point that I have marked here (showing) for the purpose of gathering the grease and oils, and things of that kind, that float upon the very top.

76. Are you able to furnish me with any estimate of the cost of this apparatus?—Yes. I can give an estimate of the cost of it, which I got from one of the most able engineers in the city. He estimated that an apparatus of that kind, 16 feet square, and made of iron, would cost about £750. That does not include the cost of putting it in its place; it is simply the cost of the apparatus as made in the engineer's yard.

77. Then you say that the estimated cost of constructing an apparatus similar to the model, but 16 feet square, would be about £750?—Yes; and it would throw 10,000 gallons per minute.

78. Do you mean that that cost of £750 would include the cost of a steam-engine to work it?—No; that is merely for the shell of the apparatus, as it were. I have no doubt that it would cost double that sum before it was put into its place.

79. Then that sum does not include the cost of a steam-engine to work it?—No.

80. Have you any idea as to the size of engine that you would require to work it?—I should think that ten-horse power would work a thing of that kind easily. Even although it was a good deal larger, I think ten-horse power would drive the extractor. Of course it is a little stiff to start; but after it is started, it goes quite easily. It does not require a great deal of power after it is once set agoing.

81. Is there anything more you wish to add to what you have already stated?—There is nothing more except I might be allowed to say something about the sanitary condition of the town; and I have a proposal to make for flooding our sewers every day, and letting the gases out of them—at least out of the low levels. I have already written to the newspapers about that matter, and my views are quite well known about the city. I propose to bring the salt water up into the sewers, instead of following Mr. Bazalgette's plan, and take away our filth from the city. I propose to bring up the water, and wash out the sewers, and retain the sewage matter, and send it to the country. I now produce a copy of the *Glasgow News*, dated 8th March 1875, containing my proposal on that subject.

82. I see that this is a proposal to bring water up from the sea for the purpose of flushing the sewers?—Yes, and also to promote the health of the city by using it for bathing.

83. You seem to assume in that letter that if sea-water were passed into the sewers, it would disinfect the sewage, and render it innocuous?—I believe I am wrong about that, because one of the principal chemical men in London has said so. One of our councillors, Dr. Fergus, and another one, named Mr. Smith, had written up to him about it; and he had replied to them that sea-water introduced into the sewers would make the gases worse instead of better. I cannot see myself that that would be so; but I think that if the sewers were flushed every day, it would a great improvement. If the sewers were cleaned out every day, the whole of the noxious gases would be put out, and the filth would be taken away, so that there would be no fear of any bad effects.

84. Then the substance of your proposal is to bring the water from the sea, and to pass it into the sewers, and also to use it for the purpose of sea-bathing; but you say that the chemists have told you that admitting sea-water into the sewers would make them rather worse than better?—Yes. I would allow the chemists to judge for themselves about that. I am not competent to express any opinion myself on these chemical matters; it is only the mechanical part that I can speak to.

Mr. William Paton Buchan, Master Plumber, 25½ Renfrew Street, Glasgow, examined.

85. I wish to say a few words upon this subject, both as a practical tradesman and as one who has taken a great deal of interest in it, and who has taken part in the controversies about it in the London and Glasgow papers. I wish to look upon the subject in a practical manner, and to give my opinion as to the way in which it should be carried out. Glasgow, as your Honour knows, is a very large city, and has a great many interests in it; and this scheme must not only take up the disposal of the sewage from the water-closets and kitchen sinks and so on, but it must also deal with the manufacturing refuse, which is very largely produced in this city. Consequently I consider that any scheme which would be worthy of Glasgow must be a comprehensive scheme, and deal with the matter as a whole, and not in a mere partial manner—dealing with one part of it here, and another part of it there. I once thought that collecting the water-closet sewage, beside the houses, from the soil-pipes was a good plan; but after considering the matter, and examining certain places which had been fitted up to carry out the proposal practically, I had to give up that idea. For example, one plan brought forward was Hoey's system, which was chiefly recommended by various parties to this city. I went with one of my men and examined that system privately, dressed as a workman, because I considered that the other gentlemen, who had gone to examine it dressed as gentlemen, had not had a fair opportunity of testing it; for the people were afraid to give them their opinions, as they might be behind with their rents, or something of that kind, and they were afraid to speak their minds. Consequently I went just as a workman, and as if I had been looking after repairs. Well, I found the majority of the water-closets on that system to be in a very bad condition indeed. They were pan-closets, and only about a cupful of water was allowed to flush the closet each time it was used. That water came when the handle was held up, and when the handle was put down the pan was left dry. The consequence was, that when the next person came to use the closet their soil stuck to the pan. Several persons did that, and the soil gradually accumulated; so that when I went to examine them the majority of the closets were in a very bad condition indeed—the soil sticking and being squeezed up between the basin and the pan, until the place was in a disgraceful state.

86. Are these Hoey's closets that you are describing just now?—Yes. Some of the closets were in a better condition, but these had been recently cleaned by the people pouring down water and cleaning them with their hands. In one that I went into the people were just in the act of cleaning it, and the smell was very bad indeed. It was in a top flat, and the people in that house said they were disgusted with the closet; and they wished it was out, because they had to take a great deal of trouble with it—carrying water from the kitchen sink to pour down into the closet every now and again. In another property which I examined, one party, when we were going up stairs, said, 'Are you at these closets again? We are about stunk out of the property with them.' The result of my examination was, that I had to throw up Hoey's system of closet; and my opinion, as a practical plumber, is, that any water-closet fitted up with only a cupful of water to flush it out every time it is used is simply unworkable. There were only two buildings in which these model closets were fitted up; and I could not help asking the question, If that was their state in these two model buildings, how would they be in the whole city? There were people looking after these properties, and going over them from day to day, to see how these closets and other things were going on; and if there had not been that constant supervision of them, they would have been in a worse condition than they actually were in when I did examine them. Then with regard to the idea of collecting the water-closet soil in large cesspools at the mouth of every close, or of so many closes, I had to give up that idea too, because a great deal of the water-closet sewage was dissolved; and these cesspools or pits, which were intended to gather it, did not collect the sewage, but a large portion of its valuable products went away mixed up amongst the water and

William Paton Buchan.

William Paton Buchan.

were lost. Looking at the matter, therefore, in the light of what is best for the comfort and health of the inhabitants, and also to allow people to have a water-closet in their houses, which is a great convenience, not only to people in health, but especially to people who are not able to go out to back doors—as when they are in bad health and so on—I consider that if a water-closet is put up properly in a house, which can easily be done now from the light that has been thrown on the subject within the last eighteen months, the provision of water-closets with a sufficient supply of water is the best way of disposing of human refuse and of soil. Consequently, looking at the matter as a whole, and in order to deal with the soil and with the chemical refuse and the manufacturing refuse, etc. of Glasgow, I consider that the only scheme yet brought forward which is worthy of Glasgow, and which will deal with the subject in a thoroughly practical and tradesman-like manner, is Mr. Bateman's scheme, or some scheme similar to his—if it can be made a better one, so much the better—of collecting all the matter which at present goes into the Clyde, and carrying it away down to the sea-coast at Ayrshire, or some such place, so as to keep the Clyde pure. That, as a practical tradesman, and on thinking over the matter, is the conclusion to which I was forced to come, having studied the matter for two or three years; and as you were sent down here for the purpose of collecting evidence, I thought it my duty to come and say a few words on the subject, especially as I had taken part in the various controversies which have taken place about it.

87. Does Hoey's water-closet differ in its structure at all from other water-closets?—It is only a common pan water-closet, and it has only a cupful of water every time the closet is used.

88. Then the main object of it would seem to be to limit the quantity of water used?—In one of the places I examined, there was a large pit dug in the centre of the building—inside the building and below the close; and the soil from the water-closets went into that large cesspool, and lay there for several days until the pit was filled up, and then it was carted away. The object in giving so small a quantity of water to the closet was because, if a larger quantity of water than a cupful was put in every time the closet was used, the sewage, they said, would be so much diluted that it would not be worth carrying away—it would not pay the expense; but I consider that that was killing the people for the sake of making a little show. There is one other remark I would make with regard to the water-closets. We have heard a great deal lately about the gases from the drains and the soil-pipes going through houses and killing the people. The reason of that is simply because the drains are improperly put in, and the soil-pipes are improperly ventilated, and also the water-closets. In one case lately where it was desired to make the ventilation as perfect as possible, in a house where the Prince of Wales was living, they carried the ventilating pipe from the top of the trunk of the water-closet into the ventilating pipe of the soil-pipe of the water-closet, which they imagined would draw up all the gas that collected in the water-closet trunk, and take it out of the house. The consequence was, that instead of that, the draught of the fires in the house drew the gas from the drain right into the house, and, I believe, was the cause of the Prince of Wales' illness. And only the other day I received a communication from a pretty high quarter—I shall not say where—recommending me to adopt the same plan. They always imagine, that the gas will go up, never thinking of the back draughts, and of the great power of a fire inside of a house. That ventilating pipe should have been sent through the wall or up to the roof of the house, so that if any draught came back it would have given a draught of fresh air, and not one of bad gas from the drain. That result, therefore, is not the fault of the drains or of the soil-pipes, but it is the result of the ignorance of the architects or others who have to do with the matter. Put up a drain or a soil-pipe properly, and you may put it in your bedroom. You may fit up a water-closet in your bedroom if it is rightly put up.

Mr. William Strang, Manufacturer, 64 Gordon Street, Glasgow, examined.

89. I have put into writing the ideas which I wish to lay before you, and I may say that I take in not only the purifying of the Clyde, but my scheme includes the purification of our sewers. The one thing follows the other when looked at as a whole scheme; but I have considered as one part of it the cleansing of back courts and the disposal of the sewage. *First*, I would give a short description of the machine to be connected to water-closets and kitchens; and I can mention where these may be seen working both in private houses and at public works. *Secondly*, I would show how I deal with water-closets connected with public works, and the public urinals in the city and at railway stations, etc., and also with the removal of manufacturers' refuse. *Thirdly*, I would give a description of the plan for removal, and the quantity of soil and urine to be removed. Then I would state how ashpits should be done away with, and how we get the manure at little cost; also where we get the filtering material, and how sewer gases would be prevented from entering dwelling-houses. I now produce a sketch of my plan, showing the idea of the water-closets. Of course we do not interfere with the present water-closets except where wanted. This plan shows the way in which we have them fitted up at our own works, and where you may see them if you wish. Here (showing on plan) is the soil-pipe; and this (showing) is the water-closet. The soil comes down here (showing), where there is a bed of ashes, and the greater proportion of the urine is found to lie here (showing); while the water which flushes this being lighter than the urine, naturally flows up through here (showing) by its own weight, and runs away here (showing), while the soil is taken away here (showing). That is one way of it. Another part of the plan shows its adaptation to a public work, where there is a large quantity; and of course the apparatus would just require to be proportionally greater. Then as to the urinals, the urine comes down here (showing), and being heavier than the water, this place (showing) is filled up with the urine, while the pure water naturally flows away, and at the same time there is always a top of pure water preserved which keeps down any offensive smells.

90. What do you propose to fill the filters with?—Ashes; the very best thing we can have, and which can be got cheaply. Given that idea of the machine, you will be better able to follow the description of my plan. The principal feature of the plan is, that it intercepts, by means of the *filter*, all the sewage from each house or tenement, and keeps back the excreta and other polluting matter, allowing only the water in a perfectly innocuous state to pass into the sewers. In proof of that, see Professor Anderson's report to the Town Council of Glasgow; also second report, dated 25th September 1869. The filtering machine is so constructed that the under part holds the urine as it falls to the bottom from its specific gravity. The soil may be divided into two. One portion, being heavier than water, subsides and falls to the bottom, mixing with the urine; while the other portion in suspension is kept back by the ashes from flowing into the drain. The water used for cleansing the water-closet passes down the soil-pipe, carrying all the soil with it; it then passes upwards through the ashes, and is filtered before passing into the drains. I have next a note of the places where these may be seen at work, and I can furnish you with it if you wish it. Then the water-closets in connection with public works, railway stations, etc., would be provided just with a machine of the same sort as I have shown on the plan, only a little larger in proportion. Next, with regard to urinals, it would be of advantage that the urinals should be filled with pure water every

day. You will see, from what I have already stated, that if they are filled with pure water, the urine coming down displaces the water, and lies under the pure water, thus keeping the urinal free from smell. The urinals would be emptied daily as with water-closet machines, and connected with the sewage pipes leading to the Clyde. I shall afterwards have to explain how that is to be done. Then with regard to manufacturers' refuse, refuse in suspension would be purified by having a good-sized filter of sand or ashes, allowing plenty of time for subsidence and slow filtration. Refuse in solution might require chemical treatment, but that of course is a very difficult thing for any one to speak of, unless they first know what they have to deal with; and as that has not come under my notice, and as I do not know the different kinds of sewage that may be coming from the different works, it is impossible for me to say how they might be treated in a chemical way. Besides, I do not profess to be a chemist; but when we have refuse in solution which cannot be purified (and this, I think, is an important matter), provision is made for the removal of all such refuse by means of the sewage pipes. These are extra pipes that would be laid down from the tanks, and they would be laid into every public work for the removal of the urine and soil; but as they would not always be in use, they might be used for running off the polluting refuse, or the refuse that is in solution, from the works to barges on the Clyde, and removed to where it would be harmless. The method of removing would be by a sewage pipe, that would require to be laid down through the streets connected to each machine. These pipes would be used for conveying the urine and soil from the intercepting machine to barges on the Clyde, where they would be collected along with the ashes—the barge to be constructed so as to receive ashes and street sweepings in the upper part, and the urine and soil in the under part. As the barge gets filled up the ashes will get saturated with the urine, and this will reduce the bulk of the ashes by about one-third. These steam-barges could remove at a cheap rate every day all the soil and urine, with the ashes, garbage, and street sweepings collected in the city to places along the coast, and sold to farmers. Another way in which it might be removed would be as it is being done in the city just now. The soil and urine taken from these machines might be removed in the manure carts, but whenever these carts pass they throw off a fearful smell. But there is another way in which it might be done. As one-half of the quantity to be removed would be water,—that is, about 100,000 gallons, taking the inhabitants of the city of Glasgow at 500,000,—then there would be 75,000 gallons urine, and 25,000 gallons soil; and it might be as well to collect all the soil in a drainer, allowing only the water and the urine to pass through the sewage pipes so as to prevent them from being clogged or choked up; and there would be so little of the soil, that mixing it with the ashes would keep down any offensive smell. *Next*, with regard to the *quantity to be removed:* For a block of houses where there are ten families, and five persons to each family, a machine holding twenty gallons would be large enough. This machine would hold for one day 10 gallons urine and soil, and 10 gallons of water, to be removed daily. It is well known that a greater quantity of water is used in water-closets, but this makes no difference in the quantity to be removed, as all extra water flows upwards through the ashes into the drain. As the bulk of sewage to be removed would never exceed 20 gallons for every fifty persons, the maximum quantity to be removed from Glasgow would be 200,000 gallons daily. To this quantity must be added all sewage coming from public works and urinals. This simple plan reduces the bulk to a quantity which can be easily got rid of.

Next, with regard to ashpits.—At present the prevailing system is to have deep ashpits, into which all kinds of garbage and ashes are thrown and stored up for weeks and months, till they throw off gases which are, to say the least, offensive. I do away with all such places, and substitute portable cans of sufficient size to hold all the ashes, etc. for one or two days.

By substituting portable cans, no time would be required for lifting the ashes from ashpits as at present, and they would save back courts from being polluted. These portable cans would be constructed to keep the ashes dry, and free from rain. There would be no necessity for manure depots, as the barges would serve all necessary purposes, and save these manure depots, which are a nuisance, and often source of complaint. The ashes, etc. would be carted to the barge, saving all extra cartage. It is of importance that everything coming from houses, whether ashes or garbage, should be removed every twenty-four hours—never allowing to lie in back courts what would not be allowed in streets for a day.

With regard to manure.—Ashes at present cost a large sum for removal, as they are comparatively worthless in themselves; but if treated in the way we propose, by mixing them with the urine and soil in the barges, we would have a valuable manure, at little cost for production. Ashes are very porous, and seem as if they were provided for enabling us to remove in a portable form the urine and soil from our cities, by mixing them together, and preparing them for the farmer. While the ashes absorb the urine and become valuable as a manure, they are at the same time reduced in bulk, lessening the cost of removal.

Next, as to the filtering material.—Filtering material comes from every dwelling-house in the shape of ashes, which make a first-class filter, keeping back what is in suspense, and deodorizing what passes through them. This material costs nothing, as it is got where it is wanted, and after being used is more valuable than before.

With regard to gases.—By placing one of the machines to every soil-pipe, it would be impossible for gases to pass into our houses. By removing the urine and soil every twenty-four hours, no time would be allowed for gases forming. The pure water passing down the soil-pipe would keep down all smell from the machine, and form a self-acting trap. The air in cities could not be tainted with sewage gases, as all impurities would be removed every day. Another advantage of the system is when fever, such as typhoid, scarlet, small-pox, etc. etc. were found in any block of houses, the soil and urine kept back by the machine might be treated with disinfecting acid before it was removed. If what comes from fever patients be allowed to run through a long drain or sewer, no one can tell how many may be affected before it becomes neutralized; but if it is disinfected before it is taken away from the house where the fever is, and if it is kept sealed with water till it is taken away, the danger is reduced to its minimum. This machine traps all sewer gases at the foot of the soil-pipe, allowing of a much simpler water-closet being used. Sewer gases at present are allowed to pass up through the soil-pipes, and trapped at each water-closet by the pan. I would do away with the pan, and have the trap at the foot of the soil-pipe for each land or block of houses by placing the machine at the foot of the soil-pipe. This would be a complete trap to all sewer gases; and by removing the pan of the present water-closet, the urine as it was passed would flow down through the soil-pipes till it reached the filtering machine; it would then pass through the water to the bottom of the machine, where it would remain till removed. The soil would be carried down to the machine by the pure water, when it would be intercepted by the ashes—the water flowing upwards through the ashes into the drain. There is one thing with regard to the rain-water which I may mention. Of course that plan would make no difference as to the rain-water, because the rain-water would not go into that pipe at all, or, if it did, it would flow away just the same as this extra water would do. Then, in summing up what I have to say, it appears to me that this machine which has the merit of simplicity, allows of the water-closet system being extended into every court and land in the lowest districts. Water is the most convenient, the cheapest, as well as the best agent known for cleansing and carrying off all impurities. Water is not only the best agent for cleansing, but it is a self-

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acting trap for keeping down all offensive smells that might come from the machine till it is removed. Water is also recommended by medical men for keeping down infection from patients, by placing under water all clothing coming from them. If useful for clothing, how much more for the excreta from fever patients. It provides a simple and cheap method of removal of all street sweepings, ashes, and water-closet filth every twenty-four hours from our city—keeping down sewer gases, by removing their source. It would check infectious diseases by keeping all that comes from fever patients from entering drains till it has been purified. It turns into a valuable manure what is at present worthless. It provides a simple plan for public works getting rid of all refuse they cannot purify.

91. Have you ascertained yourself that the difference in the specific gravity of water and urine is such that the pure water would always be at the top and the urine at the bottom?—Yes; I have tested that thoroughly. I have tested it through a stream, and you may easily test it for yourself. If you take a jar of clean water, and put a small pipe into it, and pass urine down through the pipe into the pure water, you will see that it goes down, even although the pipe is not down to the bottom of the jar; and you can see the urine going down almost like a stream of silver, while the displaced water passes up. I may say that a machine fitted up for a land of houses is not a bulky machine.

92. How often do you propose that the ashes in these machines should be changed?—If the under part is removed every day—as I think it should be, because I don't think it is advisable to keep it waiting for more than a day—then the ashes could be used for perhaps nearly a fortnight or a month. There would be so much pure water coming down the closets that it would preserve them, and the ashes would not require to be changed very much. Of course if the machine got choked up with the soil and the urine, then the ashes would become perfectly saturated, and they could not act; but if the urine and the soil are taken away before they choke up the machine, then the quantity of pure water coming down from the closets would be so large that they would act for a fortnight at least, and I don't know that they might not remain for a longer time. In fact, we have not got any test with regard to that.

93. How do you get your quantity of 75,000 gallons of urine for the whole of Glasgow?—I took the population of Glasgow at 500,000, and I estimate that there would be 1½ lbs. of urine and ½ lb. of soil for each person per day. That is the average which has been taken by persons who have been giving this matter their attention. Of course that is a matter that could easily be tested, but these are the data on which I have gone.

94. What do you propose to do with all the slops and stuff used in washing, and so on? Do you expect that to be filtered, and to pass away as clear water?—Anything in the shape of sludge would remain at the bottom, and the water would go away. Of course anything which was in suspension, such as grease, would be kept back. I do not say that the filter would make the water perfectly pure, but the ashes act as a very capital filter. I may say that the machine which I have described has been fitted up and tested in a place about which there has been an interdict.

95. Have you had an analysis of the water escaping from the upper part of one of these filters?—I have had three. There is one of them in Professor Anderson's printed report, which I see you have got.

96. Does Professor Anderson give an analysis of the water after it has passed through one of these ash-beds?—Yes. I have also another analysis, which I got from Professor Anderson myself, and of which I will send in a copy; and also one by the late Professor Penny, of the Andersonian University. I shall send in a copy of it also, and also a copy of the plan which I have exhibited.

Mr. James M'Intyre, Fyfe Park House, Port Glasgow, examined.

97. I produce a tracing, on the scale of 6 inches to the mile, showing the course of the sewers which I propose to be made on the north and south sides of the river. I also produce a model of a portion of the sewer, showing the pockets which I propose should be made in them; and also a plan of cesspools, showing the mode of lifting the water. I also put in a copy of a paper read by me before the Philosophical Society of Glasgow, in which my scheme is fully described.

98. Is your plan based upon accurate levels?—I claim that it will run exactly on the level; but it can be worked on any level, because if there was a great declivity, it would only be necessary to raise the pockets a little more.

99. But you don't propose to make it level?—No. I propose to give it the exact declivity it requires from above, whatever it is.

100. Have you made any estimate of the cost of this work?—I have got two or three estimates, but they have all arrived at somewhere about £260,000 for the north side sewer from Dalmarnock to the foot of it. I don't profess to have much knowledge of such estimates myself, but I got the estimates from those who ought to have a knowledge of them—Messrs. John Coghill & Co. and Mr. Haldane.

101. And what do you make the south side sewer?—It would not be nearly so much. In fact, I never asked an estimate for it.

102. Would it not be the most?—It would be the most, because it is longest; but it would be nothing like so high as the north sewer in proportion to its length. I do not propose, however, that the south side one should go higher up than Rutherglen, because above that I think the Clyde would be shallow enough to allow the sewerage from any towns on the south side to be conveyed across to the sewer on the north side. I propose that that sewer should begin with a certain size at the source, and increase in size between the various towns, according to the requirements of the population.

103. Do you propose to go right to the top of the Clyde?—Yes, or any other river that my system is applied to.

104. Do you mean to do that for £260,000?—No. That is only for the sewer from Dalmarnock to Erskine—a distance of about 12 miles.

105. Then you have not got an estimate of the cost of the whole scheme?—No, because I was not aware of the size of sewer that would be required at the different towns. Of course it would have to be altered in size to suit their requirements—starting, perhaps, with 3 feet, and then making it 4 feet, then 5 feet, and so on.

106. But you cannot give me an estimate of the cost of the entire scheme?—I don't think it was for me to try that; but the cost of the outside of an ordinary sewer without the pockets would be £260,000.

107. Have you anything more you wish to add? I quite understand your plan, which is quite plain and simple.—I don't think I have anything more to say.

Bailie Salmon, Glasgow, examined.

108. I have to explain, Sir John, that as convener of the Sewage Committee of the city, having heard Captain Liernur's scheme presented in Glasgow at the Social Science Congress, and having studied it so far otherwise, I applied to him to prepare a plan and estimate for the application of his scheme to a certain section of the city; and I got a plan prepared of that section, with a proper description of it, showing the character of the houses, and the drains, and other useful information, which was sent to him. Captain Liernur, on the information that I gave him, and on

the plan that we sent him of the district of the city, has prepared a plan and an estimate, and a description of the application of his system to that section of the town; and Mr. Scott, who was, I believe, the purchaser of the patent for the United Kingdom, is here to-day to explain the plan and the description.

Mr. Adam Scott, 221 Gresham House, London, E.C., examined.

109. I produce a plan of the district of Glasgow which was selected by the Sewage Committee for this proposed trial. It contains a population of about 12,500, and it is provided with sewers in every street with the exception of one. I have here Captain Liernur's report, but it is a very lengthy one, and perhaps it would be better that I should shortly describe the principle of the system.

110. I think you had better describe it in your own way.—The principle of the Liernur system as compared with other systems is to divide and conquer,—not to put into one sewer such an enormous mass of unmanageable material as is put, for instance, into the sewers of Glasgow, London, and most of our large towns, but so as to divide and conquer the difficult parts of the sewage, that the water that goes into the ordinary sewers is clean enough to go into a river without further purification. The polluting elements in sewers are, *first*, manufacturing refuse; *secondly*, human excrement; *thirdly*, street detritus; and *fourthly*, the soiled water of households. First, with regard to manufacturing refuse, Captain Liernur lays down the law, so far as he can lay down a law, and which is now apparently going to be laid down by the Government, that all manufacturers must be made responsible for cleaning their own refuse. Fortunately, in so far as legislation has hitherto interfered with that, it has been found that manufacturers have been able to do it, and actually to make a profit by so doing. I need not instance the alkaline and soda works, where that has been the case. Perhaps the most difficult of all substances of manufacturing refuse that have to be cleaned are those from dye and bleach works; and we have it now proved by Mr. John Thom, who read a paper at the Society of Arts' conference upon the pollution of rivers, that even that is possible at a profit to the manufacturer. However, the question is not whether it is profitable or not. The manufacturer must be made responsible, according to Captain Liernur's plans, for purifying his own refuse water. Whether the whole of the cost, or only part of that cost, is to be a burden upon himself, is a question to be settled between him and the public. The necessary thing is, that the stuff should be purified separately, and not be allowed to complicate the sewage question thereafter. Then, with regard to street detritus, it is of course polluted; and Captain Liernur, instead of allowing it to get into the sewers as at present, and to silt up the sewers, and finally to enter the river and silt up the river courses, proposes to insert in the street gulleys a bucket, into which all the street water flows. It flows in by a funnel, and can only flow out and in to the sewer by an upward filtration through a thickly-woven straw mat, all the detritus being thereafter thrown down into that bucket, and periodically removed by scavengers. This prevents the necessity of expensive methods of flushing sewers and of opening them, as has to be done very often for the purpose of cleaning out the deposits. In fact, it prevents deposits pretty well altogether. The third division is that of the putrescible matters in towns, composed principally, as the most dangerous refuse of towns, of human excrement, and also of solid or sedimentary matters which get into sewers generally through the house water, these being fatty and sedimentary products of food and fragments that have been partially cooked. These matters are practically the same as human excrement. They are food, but they have not yet passed through the human body, and therefore they are in that way several days less forward on the road to putrefaction and to danger to the public health. The collection of these putrescible matters is effected by what is known as the pneumatic system. Every town is divided into certain large districts, each of which is separate and independent the one from the other, as if they were separate towns altogether. In each district is stationed a central house containing a steam-engine working an air-pump. This air-pump maintains during the day a vacuum in certain air-tight cast-iron tanks below the central building, and also in the pipes extending from these tanks throughout the city. The districts, again, are further subdivided into small districts or drainage areas, each one of which centres in a small street-tank, with which each house is connected by means also of cast-iron air-tight pipes. The vacuum which I have mentioned is maintained in the central building; and the central or master pipes that run from that building can be connected to any given street-tank by simply turning a cock, and thus form the motive power for emptying the closet pipes of all the houses at one and the same time, independently of the fact that one house may be more distant than another from the tank where the vacuum power is, for the time being, stored up, and independently of the fact that one closet or closet-pipe may have received more matter than another, or may have received none at all. I shall not go into the reasons how it is that that is so, but I shall give the Commissioner some papers upon the subject, which will explain to him thoroughly the principles upon which the pneumatic system is formed. Perhaps there may be no objection to my here mentioning the fact that the senior medical Government Inspector of Holland, writing upon this system from his experience of it in that country, says, that 'for the English reader this system has a double interest. It embodies the principles which have been demonstrated in every report on the sewage question for the last dozen years at least to be the only ones upon which a satisfactory solution is attainable;' and he also quotes the official report of all the twelve medical inspectors of that country to the Minister of the Interior, stating that the Liernur system, both sanitarily and with regard to the convenience of the inhabitants, is the best system hitherto known. The great drawback in all systems of collecting human excrement hitherto has been, that if they have been dry systems, they cannot be put in operation in towns which have been accustomed to the luxuries or conveniences of the water-flushing system. This system of Captain Liernur's requires no alteration in the habits of the people who have been accustomed to the conveniences of water-closets, as a water-closet such as he himself has invented, which restricts the quantity of water to be used—somewhat like the Hoey closet in Glasgow—can also be used on his system. At the same time he provides for the poorer classes, for whom water-closets are not at all suitable, a closet in which no water requires to be used, which has nothing moveable or apt to get out of order, and which is sanitarily perfect. It would take too long to give an explanation of how that closet is formed, but I may add that it has been inspected by a number of gentlemen from this country, including such men as Dr. Buchanan of the Local Government Board; and I have Dr. Buchanan's statement made at the Society of Arts the other day, that these closets without water are superior to the ordinary accommodation in water-closet towns in this country, which he mentions as a proof of the efficacy of this particular form of water-closet. With regard to the disposal of the deposited refuse collected in these central tanks under the central building, there are two methods which can be followed. It must be remembered, to begin with, that it is in a highly undiluted state, and, therefore, that the mass of water to be dealt with is not very great. It can be used, therefore, either in the fluid condition, or, what is really the end and purpose of the Liernur system, the water must be evaporated, and the sewage derived in the shape of *poudrette* of highly concentrated value, easily transported, and that can be kept for any length of time. In order that the closets should not be made the receptacles for all the household water, Captain Lier-

Adam Scott.

Adam Scott.

nur provides, so as to be more accessible to the domestics of the house, certain slop-sinks. In this way, by depending upon the laziness of the people, the sewage under the pneumatic system will be got in the concentrated state I have mentioned. I may mention, also, that the sink sediment, which is the same practically as the fæcal matter, is also collected by this pneumatic system; and it is done in this way,—all the water of households, including the sink water, passes into a trap, and cannot escape to the common sewer except by filtering upwards through a very fine grating; all the sediment or pieces of food, generally coated with fat, remaining behind. This trap is open to the air, so that the sewers of the town have no direct communication with the interior of any house, thus doing away with all danger from that source, even supposing there were in these sewers anything which could create gases detrimental to the public health. The trap in which the sediment collects stands in connection with a pneumatic or closet pipe; and during the twenty-four hours when the pneumatic operation takes place, the trap is emptied just in the same way as the closet pipes are. The water then flowing through the sewer is household water, purified from its solid substances. In evaporating the product got at the central station, an ingenious use is made of the waste steam of the high-pressure engine by which it is collected. Of that waste steam, in the very best engines, only 8 per cent. is actually converted into motive power, the remainder escaping with the exhaust steam. It is with this steam, used much in the same way as it is already used in sugar reducing, that Captain Liernur dries the contents of the central tanks. The result, so far as has been ascertained simply by experimental trials, is a very valuable manure,—sufficient in towns with an ordinary density of population, and according to the analyses of the most eminent chemists, and the values put upon it by eminent agriculturists like Mr. Lawes, to pay all working expenses, and to contribute considerably, if not altogether, towards the interest upon the capital employed, the redemption of that capital, and sinking fund for renewal of machinery. It will be seen by the plans submitted by Captain Liernur at the request of the Sewage Committee, that not all the streets in Glasgow are sewered; and therefore it will be well to mention the principles upon which he would drain any such streets. He objects to the old system of constructing the sewers, for two reasons. The first is, that no masonry construction can possibly prevent the polluting elements in a sewer from being forced outwards, and contaminating the soil. The result of such contamination is this, that as the sewers serve also as drains for the subsoil water in dry weather, the level of the subsoil water naturally sinks down to the level of the invert of the sewer. When sudden rain comes on, the increased height of water in the sewer takes place much more rapidly than any increase of height outside the sewer could be got by the percolation of rain through the subsoil; hence there is a hydrostatic pressure in the sewer tending to burst open the drains, or at any rate to force out the sewage matter into the soil. Afterwards, with the rise of the subsoil water, it follows as a matter of course that a similar stratum of air, which has occupied the soil, must be pushed out into the town, or, as it is generally pushed out, into the basements of the houses. Captain Liernur's principle, then, is to make impervious sewers of vitrified earthenware, so that they shall not form the direct drains of the subsoil water. Then he would drain the subsoil water in the same way as farmers do by the ordinary agricultural drain pipe, fixing upon the level for that drainage as the lowest level that subsoil water generally reaches. The effect of this subsoil drainage is to keep the subsoil water always at a low level. Here and there the subsoil drains communicate with the impervious sewers, so that the surplus water of course goes off into them. The technical advantage of this system of subsoil drainage is, that the ordinary sewers can be made very much smaller than is at present the case with our ordinary sewers, because Captain Liernur has no fear of allowing his smaller sewers to become not only quite full, but even to allow columns of water in the gully pipe, so long as such columns of water are not as high in level as that of the subsoil drainage, the hydrostatic pressure of the water in the soil counterbalancing any effect that the hydrostatic pressure inside his smaller sewers would have. The effect of this, as shown in comparative estimates, has been to show that Captain Liernur's system of subsoil drains costs about half as much as ordinary drains. I have been requested by the chairman of the Sewage Committee to make a few observations upon the subject of the necessity, for the sake of health, of dealing with our fæcal matters, and not prolonging our present sewers. That is the principle upon which Captain Liernur has gone in his pneumatic system. At present it is well known that cholera, diarrhœa, and diphtheria are directly due to excremental pollution, and it is also believed in many medical circles to be the fact that small-pox, measles, scarlatina, scarlet fever, hospital fever, puerperal fever, and a number of other diseases, though not all due to excremental pollution, are to a certain extent conveyed by it. As a proof of that, take in particular this city of Glasgow, the medical officer of which, in his report for 1868, stated that the evils that were inseparable from the water-closet system were likely to be less felt in Glasgow than in many other places, owing to the considerable fall of the greater number of the sewers, and the almost unlimited supply of water by which the matter was diluted. A few years' experience seems to have convinced him otherwise, because, in 1872, he states 'that it has been conclusively shown that houses presumed to be beyond suspicion of any possible danger to health from this cause—houses in which the most skilful engineers and architects had, as they believed, exhausted the resources of modern sanitary science—have nevertheless been exposed in a high degree to the diseases arising from air in contact with the products of decomposition in sewers, and this for a very obvious reason; such sewers are usually built on high levels, where the drains have a very rapid fall.' It seems, therefore, from this, that throwing excrement into ordinary sewers, where they have the fall which is desired by every engineer, has not been a benefit to health; and this is proved by the experience of the sister city of Edinburgh. In the *Medical Journal* of that town, in the latter end of last year, a comparison is made between the Old Town and the New Town of Edinburgh. The Old Town, which is inhabited chiefly by the working classes, and consists of those large buildings for which Edinburgh is famous, has no accommodation in the way of water-closets; all the excrement is removed daily by pails or pans. In the New Town, however, which is the city of the gentry, these conveniences of water-closets are universal. It is very striking, therefore, that when you examine into the prevalence of typhoid and diphtheria, you find that in the Old Town, where this —disgusting though it may be—system of daily removal takes place, typhoid and diphtheria are, practically speaking, unknown; whereas in the New Town, with its system of water-flushing, these diseases are never absent. It is the belief that it is absolutely necessary, as it were, to imprison human excrement before twenty hours after production. That gives rise to the pneumatic system of Captain Liernur, and in fact it only carries out in practice what theoretically was laid down some years ago as being the only conditions of safety with regard to health by Dr. Simon, the medical officer of the Local Government Board, and also of the Privy Council. 'The local conditions of safety,' he said, 'are, above all, these two: first, that by appropriate structural works all the excremental produce of the population shall be so promptly and so thoroughly removed, that the inhabited place, in its air and soil, should be absolutely without fæcal impurities.' The water-flushing system, of course, can never carry out that condition of safety, because you have gases which must escape somewhere; and if they escape into the air of a town, they simply lower its oxygenating powers, and if they escape into the houses, are doubly dangerous. The second condition of safety is that the water supply of the population shall be derived from such sources and conveyed

in such channels that its contamination by excrement is impossible. Fortunately, in Glasgow they seem to have very little chance of the propagation of disease from the water supply, if carefully handled; but we had it proved at the last meeting of the Social Science Congress here that even the presence of sewer gas in cisterns, owing to the overflows going into the sewers, had the effect to a certain degree, although very minute, of poisoning the waters. I think, therefore, that a case has been made out for at any rate imprisoning all the excremental produce of the population; and that Captain Liernur's system does this most effectually will be evident from a short quotation which I would make, also from the report of the senior medical inspector of Holland, in which he says, speaking of the sanitary merits of the Liernur system: 'The excreta are, from the moment the closets are emptied to the moment the process is finished, and they are converted into dry powder, absolutely deprived of all chance of doing harm, being locked up from first to last in air-tight vessels. The powder itself is harmless, because fermentation in a dry state is impossible. The water of the excreta has also become harmless, because, being driven out by evaporation and condensed again (the vapour passes through an ordinary condenser), it returns to the public streams as distilled, and consequently pure water. The gaseous products of the evaporation, perhaps still containing germs of disease, are combined by the air-pump machine with the rest of the air, and sucked up out of the tubes and pipes into the fireplace of the boiler, and there are completely burned. No matter, therefore, how infectious the excreta may have been, their power to work evil is stopped for ever.' I now hand in certificates by the International Medical Congress of Vienna and other towns, and by the Director-General of Holland; and also copy of the *Sanitary Record*, which contains a long technical description of the system.

111. Am I right in assuming that the slops from houses and tenements are intended to pass directly into the ordinary sewers?—Those from bedchambers are recommended by Captain Liernur to be sent into his closet and to go into his pneumatic system, and to be converted thereafter into *poudrette*.

112. Then the bedchamber slops would not pass into the sewers?—No.

113. On the drawing you show what is called a sink. Does that sink communicate with the vacuum-chamber?—No; it communicates with the sewers, so that the house water may generally go into the sewers.

114. That is what I rather assumed. The water from these sinks would pass into the ordinary sewers?—Yes. There is some slop water that passes into the sewers, but Captain Liernur recommends that the slops of the chambers should be sent into the closets, as they contain matter which is valuable.

115. But the water used for washing, and containing soap-suds, and so on, would pass into these sinks and into the sewers?—Yes; diluted, however, with fifty gallons of water per head, which, I believe, is supplied in Glasgow from Loch Katrine alone, irrespective of rain-water.

116. But a little of that water goes down the water-closets?—Only a very small quantity.

117. But I am speaking of the water that passes into the sinks; that water is to pass into the sewers?—Yes, after being purified by this filter (showing on plan).

118. That filter, however, as I understand, would simply prevent lumps from passing through?—Yes; sedimentary matters. It is represented in the plan as a strainer, so that you may see it; but in reality it is a very fine grating, so as to prevent the very smallest particle from going through, and it is quite impossible for it to be choked up, because every day when the pneumatic operation takes place, the air that carries that away into the pneumatic pipe cleanses the strainer at the same time. It clears everything away.

119. It clears away the solid matter?—Yes.

120. But the liquid matter, as I understand, goes into the sewers?—Yes.

121. Have you formed any estimate as to the relative quantities of what you call kitchen slops and what you call matter from the water-closets?—No; I have no estimate of that. Of course the proportion is different in different towns, and I have no idea what proportion Glasgow would give. *Adam Scott.*

122. Can you give me any calculation, or have you formed any idea of the volume of matter from water-closets which would have to be dealt with in a town like Glasgow?—Captain Liernur in his report goes into that question fully, and gives the amount and the reasons why he considers that a certain amount would exist. He gives the quantities as the product of a certain number of inhabitants. I do not think that what he gives in his report would be a calculation based on any data given in Glasgow, but it is simply a calculation made to cover even an extreme case. He says that his improved closet would use six quarts per head per day, to be removed by the pneumatic system.

123. Then I understand you to say that he proposes to convert that quantity into *poudrette*?—Yes.

124. Have you any calculation as to the quantity of coal which would be required to convert that quantity of sewage?—Yes. The district upon which this estimate is made contains 12,500 people, and he reckons 4¾ tons of coal per day for that number as being more than sufficient.

125. Captain Liernur appears to deal only with about a gallon and a half or six quarts, but in Glasgow, I suppose, they now get rid of forty gallons per head per day. Of course a gallon and a half per head would only be a very small proportion of the water that would be passed through the tenements or houses in some shape or other. Therefore it is only a very small portion of the whole that would be dealt with by this pneumatic process, and all the remainder, whatever that remainder may be, must still pass into the common sewers?—Yes; it must pass into the common sewers, or go into the river direct.

126. Then the question is, to what extent would that remainder be in an objectionable state? I mean that it would have to be dealt with as sewage taken from the same place, which would have to be made innocuous?—On that matter Captain Liernur says it would be pure enough, in his opinion, to pass into a common river. The street detritus is all kept out.

127. That is the rain-water, which is a separate item; but he assumes that the remainder of the water used in the tenements, whatever its state may be, would be sufficiently free from objection to be able to be run direct into the Clyde. Is not that his assumption?—Yes, that it contains no solid substance at all.

128. And having freed it from the excrementitious matter, he thinks it may run into the Clyde without any danger?—Yes, without anything of the nature of sediment.

Mr. WILLIAM C. SILLAR, Victoria Chambers, Westminster, examined. *William C. Sillar.*

129. I am the representative of the A B C process, carried on by the Native Guano Company. I am a director of the Company. I am the patentee. I am very glad to have had this opportunity of personally giving an explanation of the process, because I hold that it commends itself from its simplicity, its efficacy, and its economy. It is a system of precipitation, and as such does not open the question as to whether it is advisable to have sewers at all; nor, having sewers, whether it is advisable to keep out anything from them. We take it for granted that there are sewers, and we take it for granted that the people will put into these sewers whatever comes to their hand, and that we have to treat with what we find at the sewer mouth. But the process adds to its precipitation purification, and in that respect I think it differs somewhat from other processes. We first, as soon as we conveniently can, get access to the sewer, and add to it a mixture of clay, charcoal, and blood. These three elements

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we call the purifying elements, because each of these individually has a decided purifying tendency of its own. Clay, we know, has a purifying power; charcoal, we know, has a purifying power; and blood, we also know, has such a power, although its purifying power is not so well understood as that of the other two. After mixing with these purifying elements, the sewage is all run into a precipitating tank where there is added to it sulphate of alumina. The precipitation then takes place. The deposit so precipitated contains such a very large proportion of all the organic impurities that were found in the sewage, as to leave the effluent water practically harmless; and as none of the elements I have mentioned exercises the least destructive effect upon the manurial properties of the sewage, it stands to reason that these manurial properties will be found in the deposit. The expense of the process consists necessarily in the construction of tanks; but as the precipitation by that process is as rapid as by any other known process, the expense does not exceed in that respect that of any other precipitation process, which is as well known to engineers as any simple subject can be. The drying of the deposit afterwards is entirely an engineering question, and whether it is dried by mere exposure to the air, which it does very rapidly, or whether it is dried by artificial means, is merely a question of cost. It has been dried in three ways. It has been laid out upon the ground and dried, where it dries so rapidly, that after two or three days' exposure it cracks like a clay-bed. It has been dried by Needham's pressure process; and it has been dried by revolving iron cylinders by artificial heat. In all these ways the deposit obtained has been absolutely free from offensive smell, either in the process of drying or exposure. After being so dried, it has the appearance of brown mould, and on being applied agriculturally, it has proved itself, beyond all question, of very great agricultural value. All these points are so important that we have taken great pains to have them verified, and a company was established to demonstrate them, and it spent a very large sum of money in getting the very highest talent available for the purposes of that demonstration. The company engaged the services of Mr. Crookes, F.R.S., at a very high salary, who spent twelve months in closely investigating the process. Mr. Crookes said that he would not be connected with the company, nor would he in any way move in the matter until he was thoroughly satisfied of it himself, and he devoted twelve months exclusively to the study of the process. He has given the result of his experience in a paper which he wrote to the *Quarterly Journal of Science*—a copy of which I now hand you. He also went to Paris, where he established works himself and applied the process under his own supervision; and he studied it there for six or seven months, personally superintending and examining the process in every conceivable way. The process itself was recommended to the town of Leeds, and the Leeds people very properly said that before going to the expense of erecting works, they would like to have the process tried upon one-fourth of their sewage. Thereafter tanks were constructed for one-fourth of their sewage supply, and they saw the working of them for two years before they made up their minds as to whether they would extend the system to the whole of their sewage or not. Therefore no one could have had a better opportunity of knowing or testing the efficacy of the process than the chairman of their Sewage Committee. A short time ago the people of the town of Otley in Yorkshire were in the same difficulty as Glasgow and other towns with regard to the disposal of their sewage, and for their own satisfaction their chairman, Mr. Garnet, wrote a private letter to Mr. Tatham of Leeds, asking him for his report. That report was an independent evidence as to the process, and was not given to the company; and therefore with your permission I will read it. It is in the following terms:—

'The fortnightly meeting of the Otley Local Board was held on the 19th of November 1873. Present:—Messrs. Longfield (in the chair), J. Brown, Thompson, Robinson, Payne, Lambert, Blakey, Barrett, G. Brown, and Thackery.

'At the last meeting a resolution was passed that inquiries should be instituted at Leeds with regard to the working of the A B C process of purifying sewage in that town, and the clerk read the following letter from Alderman Tatham:—

'Dear Mr. Garnet,—During the last three or four years the Street and Sewerage Committee of the Leeds Town Council (of which Committee I have been chairman during the time) have devoted their best endeavours to solve this most difficult problem of modern times, the purification of sewage in large towns.

'We have endeavoured to acquaint ourselves with every known process, visiting every place where we could see any system at work—that is, the Sub-Committee to whom the matter has been deputed year by year by the General Committee—and the result is, that although some at first were in favour of other systems when they saw them in work, the Committee are unanimous in believing that the much-abused A B C system is the cheapest and best mode of treating the Leeds sewage which we can adopt, and that is hitherto known.

'We have been driven to this conclusion in the face of much hostile criticism and professional and other opposition. We are most desirous to find out some cheaper mode, but hitherto, though some have promised off-hand great things, when tested, every process has proved inferior to the A B C.

'We have not yet received General Scott's report, but the fatal defect of his process for us is, that his primary object is not the purification of the sewage, but to make mud into cement. His effluent, so far as we have seen his process at Ealing, was not fit to be turned into a running stream without either filtration or irrigation, whilst the A B C dispenses with the need of either.

'Irrigation may do at places like Harrogate, where there is sufficient waste-land near the town on which the sewage can gravitate, but the outlay must be tenfold that required for precipitation, and the ultimate success is problematic. We have had no support from our local papers, but I enclose a slip from the *Leeds Daily News*.

'The financial result depends upon the products. Crossness and Leeds are two different places—the Leeds sewage will not cost one-half of what the writers estimate. (Much less, I think.) The value of the manure is difficult to establish; we have tried it upon plots in our own lands at Knostrop, and the Native Guano at £3, 10s. per ton compares to advantage with Peruvian at £15.

'Our experimental works are now in operation with the A B C process—they are at the service of any person who wishes to demonstrate a better plan.

'Your Committee can see the works, both the experimental and permanent—the latter are approaching completion—and we shall be glad to render any assistance, or give you every information in our power.

'Very respectfully yours,

'George Tatham.

'*Leeds, 6th November* 1873.

'The letter was considered highly satisfactory; and it was laid on the table for future consideration.'

Since that was done, the works at Leeds have been finished, and they have cost, I think, somewhere about £60,000.

130. Is that for one-fourth of their sewage or for the whole?—It is the permanent works for the whole of the sewage. After having had the practical experience of the process in connection with one-fourth of their sewage, they have erected works for the whole, and I think the cost is about £60,000. After the completion of these works, they gave permission to any person who had a process to try experiments upon them, for although they had themselves selected the A B C system, they were not so bigoted as to refuse to receive or hear of any other. Therefore several processes have been tried in these works, it is not for me to say with

what success; but we have had an intimation that after these trials are over, the A B C system is to commence working again, and I was told that they were to commence working it this very day; so that if they have not actually commenced, it will be in the power of any person interested in the subject to go to Leeds very shortly and see the A B C process actually at work there. They will see to what extent it purifies the sewage, and at what expense it does so, and what is the effect of the process generally; and I think that one personal inspection is worth a great deal of theory. The action of the A B C process is very closely condensed in a paper that was prepared by Mr. Christopher Rawson, and read before the Society of Arts. There was a conference there upon that question, and this paper says that there were four points which the A B C process professed to solve,—first, that the effluent was sufficiently purified as to be innocuous and fit to go into a river; second, that this could be effected without creating any nuisance; third, that no material was used which injures or destroys the manurial qualities of the sewage; and fourth, that it produced a manure capable of raising good crops of every kind, and that the value of such manure at least covers the expense of the process, even if it does not leave a satisfactory profit. In proof that the A B C process actually accomplishes these results, and, first, that the effluent is sufficiently purified to go into a river, we have a certificate from Mr. Tatham of Leeds, and we have also a very full report from Mr. Keates upon a three months' trial on the Crossness Sewage of the Metropolitan Board of Works. I now produce Mr. Keates' report. At an expense of upwards of £20,000, works were put up at Crossness for treating a portion of the London sewage, in order to demonstrate what the A B C process could do. Mr. Keates personally inspected the works for three months; and this is his official report: 'Mr. Keates, the Chemical Adviser of the Metropolitan Board of Works, after a careful supervision of the process at Crossness, reports as follows:—"That the effluent water was on the whole very good. The A B C treatment so far clarified and defecated the sewage that, looking solely to the physical condition and chemical composition of the water produced at Crossness, I am of opinion that such water was in a fit state to be admitted into any ordinary river without producing a dangerous degree of pollution."' You will observe that Mr. Keates speaks very carefully; for he does not say that it was without any degree of pollution, and we never professed that the water was absolutely purified. Then the Leeds people had their injunction removed, on account of the official testimony to the condition of the effluent water. Mr. Rawson, in his report, says: 'The use of the process at Leeds enabled the authorities to get their injunction suspended; and the chairman of the Streets and Sewage Committee, Mr. Alderman Tatham, on the 22d September 1873, officially testifies "that the effluent water produced by the process is sufficiently pure to be allowed to flow into the river with the sanction of the authorities."' Mr. Tatham also testified that the effluent water was in no way destructive to fish life, as fish had been kept in it for months, while in Paris, also, the most delicate kinds of fish, gudgeons and others, were kept in the purified sewage for some time. The French people, as you know, are very particular about the fish in the river Seine. Mr. Keates also testifies that during the whole of the time that the process was carried on at Crossness, there was no offence either in the purification of the sewage or in the final drying of the manure into powder for the farmers' use. Regarding the efficacy of the manure for agricultural purposes, proof ought to be given, and we can give proofs of several kinds. At Crossness 6 acres of ground were put into cultivation, and the manure made there was put upon that ground. Before being applied, it was weighed and kept under lock and key by the Metropolitan Board of Works; and so particular were they that they even dictated that we should use Chubb's locks upon the doors of the warehouse. The crops grown there were the finest I ever saw in my life. The wheat was seven feet high, and the farmer there said he never saw better corn grown, although he knew the land to be the sourest land in the county. I think from first to last the Native Guano Company have sold something like 4000 tons of their native guano, and they have never sold a ton under £3, 10s. all the time they were working. At the end of every spring they sent circulars to the farmers, asking them, for the benefit of the public, to give them a report of what the results had been. These reports have been published in two volumes of testimonials, and I know that these testimonials are genuine. Whether the reports of the farmers are true or not, it is not for me to say, but I believe them to be substantially true, for I know that my own experience of the native guano fully bears out the testimonials given. I now produce the three years' testimonials. Another question to be considered is the expense of working this process; and that is a very serious fault which Mr. Bazalgette, in his report on Crossness, finds with it. The town of Bolton, in Lancashire, adopted the process without any interference from the Native Guano Company, and they worked themselves. We asked them to give us an official report of what it actually had cost, and their foreman of works gave us the report which I now produce, and which the mayor, Mr. Cannon, certified to be correct to the best of his belief. These are facts and figures, and are therefore entitled to belief. I saw the mayor about twelve months afterwards, and I asked him if he had any reason to alter his opinion, and he said, No; that the cost in one week might have been a little more, and in another week a little less, but that, substantially, the figures remained the same as they were when that statement was given to us. The result of that statement is, that the whole expense came to about £2, 6s. 6d. per ton of the manure made, of which sum £1 consisted of costs not literally chargeable to production, leaving the result to be about 26s. per ton as the cost of manufacture of the native guano. We have always estimated, and our engineers have estimated, that 30s. per ton was what we might fairly calculate on as the cost of making the stuff, but I think we may also fairly calculate that when the thing is in actual and positive working, the cost may be less; because experience always enables people to make their working expenses less as they go on.

131. Is that estimate of cost inclusive or exclusive of interest on the cost of the works?—There is an entry there of Burgh Treasurer's statement for interest and tear and wear, £14. That is what we say is not literally chargeable to production; it is interest on the cost of works. In addition to the other papers I have produced, I now produce an official testimony from Mr. Tatham on the subject of the purity of the water. The testimonial certifies: '(1.) That the town of Leeds has disinfected a part of the sewage of the town, and are about completing works to disinfect the whole of the sewage, by means of the "A B C" system. (2.) That the effluent water produced by the process is sufficiently pure to be allowed to flow into the river, with the assent of the authorities. (3.) That the whole of the process, including the preparation of the native guano, is performed without offensive odour or nuisance.' I have also here the statement of the results of the trial of the 6 acres of ground at Crossness, where crops were grown with the native guano, under the supervision of the servants of the Metropolitan Board of Works. That report I take to be extremely valuable, because it shows us what an enormous value of material we annually destroy by our present suicidal process of throwing it into rivers. I have now, sir, given you independent testimony from these men upon all the four points I have named; and I may say that these testimonials have not been procured without a great outlay on the part of the Company. Scientific men cannot afford to give twelve months of their time without being highly paid for it. Some people make the objection, that if a man is paid for his services, his testimony is not worth having, while others say that unless a man is paid, his testimony is not worth having. I think that is not a fair way to look at the matter. When the chairman of the Local Board of

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Health at Leamington was asked, 'Have you any personal interest in this Native Guano Company?' and he said, 'No, and I never had;' then it was said, 'If you had had any confidence in it, you would have had an interest in it;' but when he retired and another gentleman came in and was asked, 'Have you any personal interest in the company?' and he said, 'Yes, I have a very great interest in it,' he was told, 'We do not believe a word you say.' And Professor Liebig, whose reputation we all know, said, that whenever a great idea was brought out, it underwent two phases; at first everybody denied its truth, and then everybody said that everybody knew about it. The A B C process has undergone both of these calumnies. At first people absolutely denied that there was anything in it; and in high official quarters, I know that it has been called a fraud and a swindle, which I know it is not; and then, when it was proved to be able to produce the different results I have mentioned, it was said that anybody could have done that as well. But if it is true that anybody could have done it, why, I beg to ask, has nobody done it, and why are our rivers polluted yet. I leave this matter now in your hands. I have given you all the information that I possess, and if there is any point on which I have not made myself clear, or on which the evidence which I have brought before you is not satisfactory, I shall be very glad to supply the deficiency. On engineering questions we have our engineer, who has put up the works for the trial of the process, which were superintended by Mr. Hawksley at Leeds; and on chemical questions we have our chemist, Mr. Crookes, who is a man of eminence and well known in the scientific world. These gentlemen will give you any information on the matters which lie in their department. I am neither an engineer nor a chemist, and I speak diffidently myself on these points; but when I have produced the reports of scientific men on these points, I think I have done everything that any reasonable man can expect.

132. Is your process applicable to the whole volume of the sewage of a town like Glasgow, or do you require a separation of what is called sewage from rainfall?—As the tanks require to be of sufficient capacity to hold a certain number of hours' run of sewage, of course the larger the run of sewage the larger the tanks would require to be, and that would entail more expense. It would be more economical to treat the contents of the sewage only than the other, but that is not necessary.

133. How is it done at Leeds?—The whole sewage comes down. There is no separation, but there is a very remarkable thing about that Leeds sewage. The difficulty that has proved the greatest there has been the dye waters. The water at one moment comes down as black as ink, and at another as red as ruddle. When Mr. Crookes got samples of all these different dye waters, he found that they were all, to a greater or less extent, susceptible to treatment by the A B C process, but after he had finished his experiments, and when he put all his samples into one mug, he found that they were precipitable with a tithe of the cost that they required when they were separate. The chemical action of these waters was such, that on one being added to another, it had a chemical effect upon it. One being acid and another being alkali, they positively precipitated each other, and therefore I believe it would be the most economical way to treat the whole of the dye waters, and everything coming down the drains, together.

134. Can you give me any information as to the volume that is dealt with at Leeds?—I think it is 14,000,000 gallons per day.

135. Is there any place near London where your process is used?—It was used at Crossness.

136. But that was only temporarily?—Yes; we are not working at any place near London just now.

137. I thought you said something about Leamington?—We got a two years' lease of the works at Leamington. That was where the Native Guano Company put up works to demonstrate the process for themselves, and to know whether it was worth while spending money upon.

138. Do you consider Leeds to be the best place where the process can be seen in operation?—They said that they were to begin to work it in Leeds to-day. Whether they have begun or not I am not quite sure, but they certainly will be working there almost immediately.

139. Have you got analyses of the effluent water after it has been purified, so far as your process purifies it?—Yes.

140. Because there are cases of which I know personally, where the water has been made perfectly clear, and to all common observers quite pure, but yet in three or four days it began to smell again.—The clear water has remained in the tanks for weeks, and we have had fish living in it. There is one certificate where it is stated that they kept fish in the water for eight months after it had been purified by the process. I think we have got some fish in the offices that have been there for three years; and in Paris the purified water was filled with the most delicate fish.

141. That would be a good test, for if fish could live in the water for eight months, it would be pure enough.—The fish did live, and they thrived in it, for they increased in size. The materials which we use are none of them expensive. The bulk of them is clay.

142. Do you use ordinary clay?—We prefer the clay because it is not only a purifier of the water, but it fits the manure for the farmers, as the less substance that is added to it the better.

143. Have you applied sulphate of alumina instead of clay?—That is what we use for precipitating; it is added after the clay. Mr. Crookes, as a chemist, has taken out a patent for himself, which we have got the working of, in which he uses what he calls basic sulphate of alumina. I cannot tell what it is, but he uses it for reasons of economy. The sulphate of alumina is the most expensive portion of the material, and he says that this basic dispenses with a quantity of it, and makes it much more economical. Of course I have no reason to disbelieve what he says, but I know that whereas, when we began the process, the sulphate of alumina cost about £7, 10s. per ton, our use of it has been so far economized, as we do not require the pure stuff, that we can get it now for £3, 10s., which is a very considerable reduction on the price.

144. You say that the cost of the works at Leeds has been about £60,000. Are these works all concentrated in one establishment?—Yes. The works are at Knostrop.

145. Are you so thoroughly acquainted with Leeds as to be able to say whether these works which you say have cost £60,000 will be sufficient to deal with the 14,000,000 gallons per day?—They are considered to be sufficient, but I ask you to remember that they have never worked the A B C process on that scale there, because, previous to applying it to the whole sewage, they have allowed these other people to try experiments, and these people have knocked the machinery about, and made alterations to suit their own plans, and the works have to be put right again.

146. What other process was it that they applied?—We were working at Bolton, but the Mayor of Bolton and the Burgh Analyst had a patent of their own, and I suppose they had influence enough to get their own process adopted, and they tried it. It is called Goodall's process, and they went to Leeds and got permission to try it there too, so that they have been trying Goodall's system at Leeds also.

147. Do you know what Goodall's process is?—It is something with iron. I am not sure what it is, but they have tried it, and ceased trying it. I think that General Scott's process was tried also, but I do not know with what results. Even if I did know, it would not be for me to say with what results it had been tried, because, being a prejudiced party, my testimony would not be very valuable.

148. Have you any means of giving me the solid quantity of manure that you get from any given quantity of sewage?—I think that, as a rule, we consider that if we put in a ton of clay and stuff, we get out 25 cwt.

149. But out of how much sewage? I want to get at the volume of sewage; for instance, what quantity

of ingredients would be necessary say for 100,000 gallons of sewage or any other quantity?—In the experiments, when I used to look to them personally, 120,000 gallons of sewage produced a ton of dry guano.

150. What weight of ingredients would you have to put into 120,000 gallons in order to get that ton of guano?—I think the actual figures are in the Bolton report. I see there that the weight of manure in one week averaged 20 tons, and they put in of clay 8 tons 5 cwt.; of charcoal, 5 tons 10 cwt.; alum, 3 tons; and night-soil, 4 tons. But then it must be taken into consideration that all those materials were moist.

151. You appear, therefore, to get the same quantity of guano as the quantity of materials you put in?—Yes; but these 20 tons of guano are dried by heat, while the clay would have 20 to 25 per cent. of moisture, and the charcoal would have 50 per cent. I think we have an estimate that 20 cwt. put in brings out 25 cwt. of dry guano. I may mention, although perhaps it does not bear on the present question, that the price which the Blackburn people had to pay for their farm was about £200,000, being, I believe, about 60 or 70 years' purchase. They got compulsory powers from Parliament to purchase, and the price they had to pay for their land was something fabulous.

152. Have they got an Act for making a sewage farm there?—They got an Act with compulsory powers to buy the land, and they could not agree about the price. The consequence was, that they left it to arbitration, and the arbiters did give them a sum to pay.

153. How near was that farm to Blackburn?—I do not know; I have not been there.

154. Do you know what they are doing at Birmingham just now?—The last I saw of Birmingham was, that they were treating their sewage with General Scott's process, and taking the deposit into the ground all round it; but Birmingham is a very curious place, it is so very much mixed up with metal works, that I question whether a deposit from Birmingham would have any manurial properties at all. I think it would be of no use to attempt to treat it on that ground, because its chemical and mineral works have some deleterious effect upon the manure.

155. They have got plenty of these works in Glasgow?—It would not be difficult to separate anything that would destroy the manure; and it would be a great pity to destroy the manure simply for the mixture of one or two things in it.

156. I thought you said that Mr. Crookes said there was no harm in letting all these things stay in?—These were things that came from the dye-works. Colouring dyes do no harm. I do not know what effect the quicksilver, arsenic, and things that come from tin works and the like would have. They would destroy fish life; but there is nothing in clay, or charcoal, or blood that has any evil effect either on manure or on fish life. Lime has such an effect, and I should be very sorry to allow lime to go into any river. Sulphate of alumina is harmless in the quantity in which we use it. But the proper way to try these things is for people to take a small portion of the material and put it on their own ground. That has been done in the case of the A B C process, and we have got official reports of what the result is. There is one very remarkable fact that has come before us, and which I may mention. It was a matter of theory at first, but it has since been proved to be a fact, that the manurial value of solid matter is nothing compared with the manurial value of liquid matter, and almost the whole manurial power is in the urine. When we took the native guano and mixed it with the same weight of night-soil and tried them together, they were tested carefully by the Leeds people, and they found that the guano was better without the dung than with it. That seems a very curious fact, but a medical man explained it to me in this way: he says that the moment an animal eats its food, what it swallows is divided into two parts—the useful and the useless. What is useless passes through the bowels that very day, and forms the bulk of the dung; while the rest, which goes into the tissues of the body, takes its place, and displaces there a thing which has already done its part, and which is daily passing away in the shape of urine; and that the reason why guano has a higher fertilizing power than other manure is that birds do not make water, and the urine and the dung are all in one. You may have noticed in the case of a farmer, that he will use dung which he has got from a gentleman's stable; but if it has been got from a livery stable it is hardly worth carrying away, because they economize the straw, while in a gentleman's stable they give plenty of straw, and the straw takes up the urine and retains it. The urine is the valuable property.

William C. Sillar.

Mr. R. S. Syminton, Telegraph Engineer, 24 Oswald Street, Glasgow, examined.

R. S. Syminton.

157. I have brought here a model, of which I shall read a description. My system is one of filtration for catching the refuse at each tenement, and the model which I have here is made to serve for two tenements, when placed on the boundary between them. The following is the description of my apparatus, which is called 'The Deodorizing House Ash-bin and Sewage Purifier:'—

'A new sanitary appliance, combining in a portable and sightly iron structure a simple and effective method of purifying the sewage of dwelling-houses, and deodorizing all household refuse in town or country (and not interfering with the existing water-closet system).

'The structure occupies very small space—measuring 7 feet long, 5 feet high, and 2½ feet broad, and comprises "ash-bin," "filter," and "receptacle" for all household refuse. It is so planned that it can serve for either one or two separate houses or tenements, if placed on the boundary with the end projecting into the adjoining property; it provides both with independent accommodation, and may be placed on the ground level, or in a sunk area.

'The two upper ends of the structure form "filters," which are charged periodically, one with household cinders, the other partly with cinders and partly with animal charcoal.

'The upper centre compartment forms a chamber which receives the excreta from the water-closets, and is so constructed that the solids are retained hermetically in the chamber, while the liquids are filtered (upwards), first through the cinders and afterwards through the charcoal compartment, causing the water to pass off pure into the sewer or stream.

'The two lower ends form convenient "ash-bins," etc. A door on being opened presents two hoppers—the wet or soft matter (such as vegetable and animal refuse) thrown into the lower hopper is deodorized by the dust and small cinders thrown into the upper hopper falling on an inclined grating or riddle.

'The lower centre compartment retains the larger cinders for the recharging of the "filters" from time to time.

'Convenient arrangements are provided for the periodical removal of the soil, ashes, etc., the whole (mixed in the process of removal) forming a valuable manure.

'The adoption of this appliance, either in town or country, cannot fail to add to the health and comfort of the community, as all offensive and dangerous cesspools and dungsteads can be dispensed with. Complete isolation is secured to the tenement from the gases of polluted drains, sewers, and rivers, and percolation of sewage impurities into drinking wells is thoroughly prevented.

'*P.S.*—This appliance is particularly adapted for houses at the coast or in the country where there is no proper system of sewage pipes, and where offensive matter is often run into the sea or the nearest stream, forming a nuisance to the inhabitants, and often producing disease and death in our most salubrious situations.'

The witness then described the various parts of the model.

R. S. Symington.

158. What your apparatus proposes to do is to filter the liquid part of the sewage, but the solid part, the excreta, is taken away bodily?—Yes; it is taken away solid.

159. Mixed with ashes?—Yes.

160. Do you propose to make it of iron?—Yes. Part of it might be made of slate or stone, and part of it of iron. Those that I have made hitherto have been of iron.

161. What would be the cost of it?—£30 for two tenements. The model which I have shown could serve for two villas or two tenements, being £15 for each house. There are double hoppers for the ashes and refuse.

162. Suppose you were to apply your apparatus to one of the tenements in Glasgow which are divided into numerous houses, how many houses do you think it would serve?—I estimate that this apparatus, emptied once a fortnight, would do for a tenement containing twenty-four persons.

163. And at the same cost of £30?—Yes. Of course, you could empty it once a week, and then it would do for forty-eight persons.

164. Is it in operation anywhere?—This double filter is not in operation yet. I expect to have it in operation in a very short time, but I have had the single filter in operation. This is Strang's principle. Mr. Strang has a patent for the same thing; but I repeat the process, while he only filters once.

165. Is the one devised by Mr. Strang in operation much?—It is in operation in a few places in Glasgow. Mr. Strang has already been examined to-day. He has these filters in operation at his own mill at Bridgeend, near to Glasgow Green, and it is in operation in one or two tenements on the south side of the river, and has been very successful. This one repeats the filtration, and makes the water absolutely pure. I have had gold fish living in it.

166. Then you consider this to be an improvement on Strang's?—Yes. I have an arrangement with Mr. Strang to introduce it. The two patents are combined. There is one of full size—not in operation, but for exhibition—that can be seen in the Burnbank Drill Hall in Great Western Road.

WEDNESDAY, 19*th May* 1875.

William R. W. Smith.

Mr. William R. W. Smith, Merchant, Glasgow, examined.

167. I think it right to say at the outset that, as a citizen of Glasgow, I was very violently opposed to this Commission; and, in order that you may clearly understand the grounds of my opposition, I lay before you the letters I wrote at the time opposing its issue. Of course my opposition was not made on personal grounds, for at that time I knew nothing whatever about who was to be appointed Commissioner, but having for a very long period given close attention to this sewage question, and having posted myself up with regard to it from all the sources from which I could obtain information, as well as from my own experience, I came to the conclusion, after I had seen the fourth report of the Rivers' Pollution Commissioners, that we had there as much reliable information as we could possibly obtain on the subject, and that was the subject of my contention, which was so serious that Mr. Marwick thought it necessary to answer my arguments to a certain extent, although without naming me, while the *Herald* devoted a special leader to me. With regard to the question itself, I can only say that I fully endorse in every respect the conclusions of the fourth report of the Rivers' Pollution Commission. After long experience and study, I am perfectly satisfied in my own mind that we can find no other course than the course laid down there, whereby we can cleanse our cities. I am very much strengthened in that conviction by a speech delivered some time ago by Lord Derby to the Conservative Working Men's Association in Liverpool, from which I would read a short extract. His Lordship said: 'It is quite on the cards' that the next generation may find out that the gigantic drainage works, on which so many millions have been spent, are comparatively useless; and what we want now is not so much a few schemes of national dimensions, as a more minute and careful supervision of local details which do not make any particular show, but which, being looked after or neglected, constitute the whole difference between a healthy and an unhealthy district.' In that short passage you have the text of any suggestions that I would make to you.

168. When was that speech delivered?—A year or two ago. It is dated 9th January, but there is no year given. I think, however, it must have been in 1873 or 1874. In speaking of the general question of sewage, I divide the sewage of our towns into three parts. I take, in the first instance, the excreta sewage; second, the manufacturers' sewage; and third, the house sewage and street sewage. With regard to the excreta sewage, I lay it down as a standing axiom that it must be kept out from the sewers and from all connection with our houses, inasmuch as you have had ample details of the danger arising from that source and from the sewer gases. The first question to be considered is how that excreta sewage is to be kept out from the sewers. On that matter I submit to you, in the first place, a paper on the charcoal system, by Mr. Stanford. That system is in work in Glasgow, and you can see it in my own office privately; and you can also see it in public works, where there are large numbers of people working. I next put before you Hoey's system. I have been unable to lay my hands on the paper describing Hoey's restricted closet system, under which a restricted quantity of water is used, but I have no doubt you have heard of that system. But Hoey's system proceeds upon another principle than that merely of restricting the quantity of water. It has a tank in the street, or in a back court, into which the present water-closet system is run, and from that he exhausts the material by pneumatic pressure. Therefore, by having an air-pipe from the tank put through the houses no gas can ever find its way into the houses, because the matter there is removed every week, and the cleansing is perfect. Supposing the slightest smell should arise, you have the remedy in your own hands close by, because you can deodorize the matter in the tank, after cleansing the tank also. It has no overflow into the sewer, and the arrangements are of the most perfect kind. There are, therefore, these two systems—Stanford's and Hoey's; and these would, in the first instance, do whatever we wanted for a dry principle, and they will do whatever we want in connection with the present accommodation of water-closets. These two systems, with one that was laid before you yesterday by Mr. Strang, were experimented upon by direction of the Board of Police of Glasgow; and I now put in a report by the City Analyst on the subject, which he presented to the Board of Police. You will see from that report the possibility of working these processes, and the cost requisite for working them. I have also made some calculations, which I shall hand in, based upon the cost as furnished by the late inspector of cleansing for the city, Mr. Ellison. That estimate of cost has reference to the year 1873, when labour was rather higher than it is just now; but still you will be able from that to see the cost of working this closet system, supposing we have 40,000 closets in Glasgow.

169. The report by the City Analyst which you have put in is not upon Hoey's system alone, but it is upon all the three?—Yes. In the first place, with regard to Strang's system, he uses the ashes, as he calls them, but they are not the ashes; they are the ashes and cinders mixed, and perhaps there is no possibility of finding a more filthy material, or a more abominable deodorizer, among the whole matters that can be used for that

purpose, than ashes and cinders. I employed those matters for some time, but I came to be convinced that there was a singularly unpleasant odour that arose from them, and I wrote to Dr. Angus Smith of Manchester on the subject, and asked him if he could direct me to any chemical researches on the emanations from a mixture of ashes and excreta. He wrote me in reply a very long letter, and said: 'You have started an entirely new point. There has been no investigation on that matter that I know of, but I am at present engaged on some investigations on a similar matter, and I will see you shortly.' Afterwards, when he was in Glasgow, he called at my office, and said: 'You have given me a horribly dirty job.' I said, 'How so? It is a very important job;' and he said, 'I see that it is more than ordinarily important, and I will see how I can get at some result about it.' Dr. Smith was then engaged on his book on *Air and Rain;* and the result of my speaking to him was that he went into the subject of middens, which he had no intention of doing before, and he there observed, as you will find at page 8 of his book, that the quantity of carbonic acid in the air of middens was ·7850. He says: 'Some people will probably inquire why we should give so much attention to such minute quantities—between 20·980 and 20·999—thinking these small differences can in no way affect us; but supposing its place occupied by hurtful matter, we must not look on the amount as too small. Subtracting 0·980 from 0·999, we have a difference of 190 in a million. In a gallon of water there are 70,000 grains,' and so on. Farther on he says: 'But we drink only a comparatively small quantity of water, and the whole 13 grains would not be swallowed in a day, whereas we take into our lungs from 1000 to 2000 gallons of air daily.' Then, again, he speaks of the same condition of things at page 55, where he says: 'In the above analysis the air containing ·0774 is really worse than that containing ·1604, and even ·3, because over the middens there is a little sulphuretted hydrogen.' It is well, then, in such cases to use the double test.' I shall give in a reference to these passages in Dr. Smith's book, so that you may be able to refer to them afterwards. Now the causes of that are not far to seek. I have here an analysis of coal ashes used for the dry-closet system, made in January 1870 by Dr. Wallace, which shows of what these are composed. The analysis is:—

Carbon (cinder), ...	21·46
Silica, ...	57·08
Alumina, ...	15·80
Oxide of iron, . . .	2·18
Lime, ...	1·39
Magnesia, ...	1·06
Sulphuric acid, . . .	·86
Phosphoric acid, . . .	·17
	100

You have there 1·39 of lime, which diminishes and, in fact, destroys the value of all these other materials as deodorizers; and these coal ashes are the thing that I am telling you it is such a mistake to have ever employed. In fact, I have come to the conclusion, as the result of my own investigations, and from the analyses of Dr. Wallace and Dr. Angus Smith, that this mixture of excreta and coal ashes ought to be prohibited by law; for I believe it is one great cause of the bad air which we find in our large cities. In Birmingham it was found that there was an area of something like 13 acres existing of middens; and I have no doubt that in Glasgow we have an area of 20 acres, lying covered with putrefying matter to a depth of 2 feet. In fact, these things will require to be entirely prohibited, if we are to have good health in our cities. I think that disposes of the excreta sewage of the cities; and the next thing I come to consider is the manufacturers' sewage. In the year 1869 I obtained from Dr. Wallace (who has been of very great assistance to me in these inquiries, and who, knowing that my labours have been *con amore*, has given me the benefit of his scientific labours without cost) an analysis of the pot-ale sent out from the distilleries. The result which he brought out, with regard to the ale sent out from one of our distilleries in Glasgow, was rather startling. He says: 'Taking the distillery dreg at 500,000 gallons in six days, this is 83,000 gallons in one day; each gallon contains 118 grains of ammonia, or nitrogen equal to that, so that the daily discharge of that dreg (or pot-ale) is equal to the total excreta of 48,970 persons per day. This one distillery therefore discharges as much fertilizing material as one-tenth of the population of Glasgow.' We made such an agitation about this matter at the time that the distillery to which this refers has since stopped putting this material into the sewers, and is now realizing from £1000 to £2000 a year out of that refuse, which formerly polluted the river. Now this ought to be the basis of all our dealing with manufacturing sewage; and I have laid it down as a principle that all manufacturers' sewage must be cleansed, and not allowed to pollute our drains.

170. What was the name of the distillery from which the pot-ale was obtained of which you gave the analysis?—The name at that time was Mr. Macfarlane's distillery at Port Dundas, but the practice has since been stopped. I merely put in the analysis to show what can be done in that direction. Now this is the basis of all the dealing that I would have with that manufacturing sewage. I should plainly and simply lay down the law to the manufacturers: 'Cleanse your sewage. If you can cleanse it at a cost, you must cleanse it.' A paper manufacturer up the Clyde said to me: 'We can cleanse the sewage that we put into the river, we admit; but we shall not do it until we are compelled.' Now, I hold that any man who will say that, when speaking of the damage he does to the river, and the annoyance which he causes to his neighbours, deserves very little mercy at our hands. But here comes in an exceedingly difficult question. There are many large chemical works which pour out vast masses of chemical materials, the cleansing of which would simply destroy the conditions of their existence. Suppose, for instance, that at St. Helen's, or down at Irvine, there is a large chemical work, and it is only surrounded by the population, or very little else than the population, who work at that chemical work, you can at once see that the tax upon that district would be so grave a charge upon it as simply to ruin the whole of the people, or to ruin, perhaps, the proprietor. Now, I hold that a work placed at St. Helen's or down at Irvine is a work belonging to the country; it does not belong to the special district; it is no specialty of the work of that district; it simply happens to be set down there for very special purposes; and I should say—and this is a principle which I hope will soon be recognised, for I believe it is a true one—that whenever, under proper Government chemical inspectors, the chemical sewage is found of so great an amount or weight as to be a serious drawback and a hindrance upon the work, or a serious tax upon the district, the cleansing of that manufacturer's sewage should fall upon the Consolidated Fund of the country, for it is a business of the country. That idea, I know, is a perfectly new one.

171. Perfectly new.—But I am sure it is an idea that will be recognised sooner or later; and if you think a little over it, I have no doubt it will commend itself to you. It is all very well for a large taxable area like Glasgow to bear these things; but when you come to take into consideration the fact which I will tell you, that four or five of the paraffin oil works in the centre of the country, in the Bathgate district, are at present putting their heads together to see how they can make from twenty-five to thirty miles of sewer to carry their refuse to the sea, you will see that that is a task beyond the power of any manufacturing concern in a small district to bear. I learned that fact from one of the managers of one of the oldest and most important of these concerns, who told me that such a thing was really in contemplation, and that they were considering whether they could overtake it, or whether it would

William R. W. Smith.

ruin them. What they would do, they did not know, but they seemed to think that that was the only course which they could follow.

172. Where are these works?—They are situated in the centre of the country, about Bathgate, half way betwixt Edinburgh and Glasgow. They think their only course is to carry a sewer a distance of twenty-five or thirty miles to the sea, if they can get it through the intervening land; and you can easily see what difficulties they will have to meet with regard to the rights of proprietors in passing through their lands, and the cost of bridges and culverts to carry such an enormous sewer for such a great distance. Now, if we are to have our rivers purified from a contamination such as paraffin oil works make,—which does not leave the river until it finds the sea, for you will find the contamination from the paraffin oil thirty miles distant from the works, as perfect as when it entered, and no aeration seems to remove it,—then I believe that you must ultimately recognise the principle which I have laid down, that if the works are to remain where they are, and the district where these works are is not to be utterly ruined, and the works themselves are not to be ruined, we must place on the Consolidated Fund the cost of cleansing that part of the sewage where it is found impossible for the parties themselves to bear it.

173. Would you propose that the Consolidated Fund should be charged with the cost of making that thirty miles of sewer which you have spoken about?—I would propose that whatever is necessary to keep it out of the river, and to cleanse it, should be done; but I don't think that will come to a very serious affair, because the great mass of chemical sewage which is put out from works will be found capable of being conserved at its own cost. That, I think, has been almost incontestably proved, but I have no doubt in my own mind that the ultimate result must come to something of the kind which I have stated, otherwise particular districts will be so heavily burdened, that they will be unable to exist under the burden. There is no other way in which those businesses which constitute the strength and power of the country can be preserved. If, instead of throwing the burden on the works themselves, the burden is thrown upon the district alone, then that district reaps no advantage from it, except in so far as the labour required for the works is taken from the district. The profit derived from the business is not of much advantage to the district, because, generally, such businesses are conducted almost entirely in Glasgow, while the works may be ten miles distant.

174. Don't the Rivers' Pollution Commissioners, in the report which you say you adopt, deal with refuse from paraffin works? Do they give any chemical means for getting rid of that refuse?—They don't give any chemical means. They don't go into detail. In one of the letters written by me, and of which I have handed in a copy, you will find the recommendations and conclusions of the Commissioners.

175. Would you be in favour of enacting the standards of purity given by the Commissioners, and insisting upon them?—There would perhaps be a difficulty in the way of enacting these standards of purity.

176. But you have already said that you adopt the report of the Commissioners absolutely; and that is why I ask you whether you would be prepared to enact these standards of purity?—I adopt the report in its recommendations. The standards of purity are a difficulty, I admit, and it is in order to meet that difficulty that I am endeavouring to show you that part of the manufacturers' sewage should be thrown upon the Consolidated Fund. I freely adopt the recommendations of the Rivers' Pollution Commissioners, and also their purity standards; but I say that which the Rivers' Pollution Commissioners' report has not said, that if the cost to arrive at these standards of purity is so great as will close the manufactories or hurt the district by reason of the taxation which it would involve, then that tax should be thrown upon the Consolidated Fund, because it is one of the businesses of the country.

177. Is not that like saying that you adopt these recommendations, but that whenever difficulties are found which would become expensive to the manufacturers, then the Government shall bear the expense?—No; I don't say that that shall be the case when they are expensive to the manufacturers.

178. Or too expensive?—Yes, too expensive; and that is tantamount to saying that the Consolidated Fund should bear the expense when it would be too great to be borne by the manufacturers themselves.

179. Who would have to ascertain the fact whether the necessary processes were too expensive or not?—I should put these works under Government inspection, as the alkali works are at the present moment. I should put them under a similar class of Government inspectors; and if the Government chemical inspectors said, 'You can cleanse your sewage by this process, and the cost to you will be so and so,' then I should say that the manufacturers should bear that expense. I would make these inspectors hired and paid men, the same as the alkali inspectors are at present; and I should say to the manufacturers, 'You can cleanse your sewage at such a cost, and the loss to you will be so small that you must endure it.' But on the other hand, if the loss to the manufacturer is to be so great that he cannot bear it, then he should get a warrant or order entitling him to receive so much out of the Consolidated Fund.

180. To whom would you delegate the power of finding out whether the loss was to be such as the manufacturer could bear, or that it was so large that he could not bear it, and that therefore the Government should bear it? Would you delegate that power to the Government inspector?—Clearly.

181. Don't you think that that would be somewhat like authorizing the Government inspector to tax the country at discretion for trade purposes?—By no means. The country is taxed at present in order to prevent the pollution of the air by the alkali works. Dr. Angus Smith is one of the inspectors in connection with these works, and they have the duty of going round and examining the works, and seeing that no noxious vapours escape into the atmosphere. They have carried out that until they have reduced the quantity to 5 per cent., and I believe they have now told the manufacturers that they must come down to $2\frac{1}{2}$ per cent., or even to 1 per cent.

182. Do the Government pay for that?—The Government pay these inspectors.

183. That is a different thing. Do the Government pay the expense of the process?—No; but that is the very point I wish to draw your attention to. So long as carrying out that process would be a gain to the manufacturer, or so long as the cost to him would be a mere trifle, I would say to the manufacturer, 'You must cleanse your refuse.' It would only be in very exceptional cases where the Consolidated Fund should be called upon to give assistance; and that should only be done where a thoroughly-trained chemical inspector had stated to the Government that the carrying out of the process at the cost of the manufacturers would ruin the trade, and that something must be done for them. My own conviction is that the cost of this would not come to more than a few thousand pounds a year, and unless that were done it might lead to the destruction of various houses in various trades in this country. There are only a very few exceptional cases in which the necessity for such assistance would arise; and though you were to tax the country for the chemical manufacturers in one district, you would require to tax it also for them in another district. If you were to tax the country for the cloth works in one district, then you would have to tax it for these works in another district. There are various districts in which such manufactories are carried on. For instance, we have the Galashiels district, and we have the West of England district, where cloth works are established; and we have chemical works all over the country. I cannot see my way out of this difficulty in any other way than I have stated, and I have studied it for a very long time; and I put it before you as the only course which will relieve us of a vast difficulty. We can cleanse our manufacturers' sewage to an enormous

extent if we choose, but the difficulty is to get manufacturers to do it. As I already mentioned, a paper manufacturer on the Clyde said to me, not long ago, 'I can stop my soda waste; I can stop the pollution of the river; but I won't do it until I am compelled.' The fact is that he can stop that pollution; and that he can do it to a profit is incontestably proved. Therefore I say that if we have inspectors with regard to this matter, as we have inspectors with regard to the air from the alkali works, we shall, by exactly the same principle, arrive at an exactly similar conclusion. I wish now to put in for your consideration two volumes of pamphlets, which have been in the course of collection by me for a number of years. I don't expect, of course, that you will read them all; but you may skim them over, and perhaps get some information from them. One is a volume of pamphlets on the purification of the Clyde, and the other contains pamphlets on sewage. Then, with regard to the house and street sewage, which is the third division that I have made on the subject, I have one plan to put before you which has presented itself to me as unquestionably the best that has appeared in point of cost. It is by Mr. Robertson, civil engineer, Glasgow. After we remove the excreta and the manufacturers' sewage, we shall then have only the house sewage and the street sewage to deal with; and that, I believe, we could deal with at a very moderate expense by having an overflow, so to speak, off the river, as shown in Mr. Robertson's plan. Here (showing on plan) is Glasgow; these (showing) represent two main drains, brought down to tanks here (showing); this (showing) represents a river wall up to this point; these (showing) represent floodgates upon it; and this (showing) represents a tidal reservoir. At high water this (showing) is shut, and, as a matter of course, the tanks are then open, and their contents are swept into the sea. Now, as it would only be the house sewage and the street sewage that would have to be dealt with in that way, these tanks, having to lie for six hours, could be in sets, and a large quantity of the silt which exists in the bottom of our river would be cleared out.

184. What would you say to depriving all those men who have property adjoining this large tidal reservoir of their frontage to the river? Whose property is this here (showing on plan)?—The property here (showing) is Lord Blantyre's, but there is a large bank of sand covered by the tide up to this point (showing). This is Lord Blantyre's property up to Erskine Ferry; but there would be clean water here (showing) at all times; there would never be any sewage. The sewage must go down the Clyde as usual. However, the plan itself is quite distinct; and of all the schemes which you will find among these pamphlets, this one has commended itself to me as perhaps one of the simplest and best. This place (showing on plan) could be used advantageously for floating timber and other things of that kind, where at present there is neither more nor less than sand-banks. Mr. Scott's pamphlet is also in this volume; but I think Mr. Robertson's scheme is superior to Mr. Scott's. It is the same sort of thing, but I think a better scheme. That is all which I have to say about the third division of the sewage. There is only one other point to which I have to ask your attention. I have here an article on the pollution of the Clyde, which was published lately in the *Glasgow News;* and in it you will find it stated, that at an extensive cotton mill in Lanark all the pollution is kept from entering the river. I put that in as an argument in favour of the principle which I have laid down with regard to manufacturers' sewage.

185. What is the name of the mill?—New Lanark Mill. I say that if one mill can do this, then every other mill can do it; and if it is not a cost to them, it would not be a cost to anybody else.

Mr. JOHN CARRICK, Master of Works, Glasgow, examined.

186. When I attended here on Monday, I submitted the reports which the Town Council possessed upon this subject; but during the last few years there have been many schemes sent in to our office, and perhaps it is as well, in case the parties themselves do not think of appearing before you, that I should submit these plans for your information in considering the general question. These plans are all more or less confined to the mere question of dealing with the sewage of Glasgow; but before laying them before you, allow me to refer to another matter, which may be of some importance in connection with the purification of sewage. It was only communicated to me the other day, but it relates to a point in the inquiry which may be of some consequence. It is explained by the following letter:—

'280 BATH CRESCENT, GLASGOW,
'*4th May* 1875.

'J. CARRICK, Esq.

'Dear Sir,—Herewith I have pleasure in handing you two samples of the Glasgow Bridgeton sewage kindly sent me in January last from your office.

'The sample marked A is the sewage as received from you, after keeping in the light on my office desk for three months.

'Bottle B is a sample of the same sewage, which was filtered through about 3 inches deep of crushed oil-works shale (a substance consisting chiefly of aluminous earth, associated with finely-divided carbon).

'The two samples have remained side by side on my desk, and now you will notice the unfiltered sample stinks most abominably of sulphuretted hydrogen, whilst the other is odourless.

'I may mention that there is practically an unlimited supply of this deodorizing agent, which is at present quite useless—probably a constant yield of nearly 1000 tons daily within 30 miles of Glasgow.

'I have shown the samples and similar notes I now give you to a recent meeting of the Glasgow Philosophical Society, and should be pleased, if you think fit, that you should mention the matter to Sir John Hawkshaw; but I have no desire to thrust myself prominently forward as a "Sewage Philosopher."—Dear sir, yours truly, 'J. I. COLEMAN.'

Accompanying that letter were the two samples which I now produce. I don't know Mr. Coleman; he is a stranger to me; but I thought it of some importance that you should have the result of his experiment. The sewage was taken from the Bridgeton sewer, which is discharged into the Clyde above Glasgow. The change is certainly a remarkable one; and as it is effected by a substance of which there is an unlimited quantity, this is a very important matter. I now produce plan of a scheme that was submitted to the Lord Provost of Glasgow by Mr. A. D. Stevenson, C.E., and it seems to have received from him considerable attention. It is on the principle of intersecting the sewage at different levels, and the small hand-map which I now produce shows his whole scheme at one glance.

187. What is the date of it?—There is no date on it. It came into my hands last year; and it has evidently been matured by him with great care. I have the other plans of the scheme here, but the small map gives a bird's-eye view of it.

188. Did Mr. Stevenson make any estimate of the cost of the scheme?—No.

189. Or any report?—No. There was just a simple letter to the Lord Provost, and of course at that time we had in view this inquiry by some person like yourself, and we took no steps in the matter. The scheme is confined purely to Glasgow, and Mr. Stevenson has taken it for granted that irrigation was the proper mode of disposing of the sewage. Then, about fifteen years ago, Mr. Smith, C.E., prepared, under my direction, a scheme for carrying away the sewage of the high levels of Glasgow on the north side of the river, and utilizing the sewage, by means of irrigation, upon the low land on the banks of the Clyde lying between the river and the high land, which is almost formed by the contour line of the Helensburgh Railway. This

John Carrick.

scheme is also taking it for granted that irrigation was the best mode of disposing of the sewage, and was, I may say, suggested to myself by a visit to the meadows at Craigentinny, near Edinburgh, where the application of sewage to irrigation is done so cheaply. What occurred to me was this, that intersecting the high-level sewage of Glasgow, embracing the high parts of the town and the West End Park district, and conveying the sewage across the Kelvin just at the Park by a high-level bridge, and then by means of a tunnel finding a way to the district lying in the neighbourhood of Yoker, we could by that means have it at such a level as would place something like 2000 acres of land on the banks of the Clyde on the level of the sewer. The matter never was gone into at all, except that it was considered by all parties as one mode of dealing with the subject, but it was delayed in view of a more comprehensive scheme for dealing with the whole sewage of the city. I have thought it right to place this plan before you, as it may be a question how far other parts of the valley of the Clyde may not be dealt with in that way. Then in 1869 Mr. George Thornton, C.E., now residing in Brussels, prepared a plan, and a very elaborate report upon the drainage of the sewage out of Glasgow and the purification of the river Clyde. This report and plans have been in my possession ever since, but the scheme has never been submitted to the Town Council. I wrote to Mr. Thornton when I heard of your intended visit here, requesting that he should appear before you and submit his plans, but he has not made his appearance, and I am just in a difficulty as to whether I should lay the plans before you or not.

190. I think it can do no harm that I should have the report and plans before me. They may contain some information which I have not got otherwise.—It is a totally different plan from any other that has been suggested. Mr. Thornton proposed to intersect all the sewage of Glasgow and convey the same to the foreshore of the Clyde lying below Erskine, and between Erskine and Port-Glasgow, and by reclamation of the foreshore obtain a large area upon which he proposed to precipitate the sewage of the river. This report gives you the details of the scheme, and I need not trouble you with them; but he may perhaps wish to communicate with you himself. I believe that since these plans were prepared, Mr. Thornton has revised the scheme again, and he may be prepared with further information. He proposed to utilize the high-level sewage so as to raise the low-level sewage, I believe, by means of mechanical appliances. I now produce his section through the city, and also his report.

Gavin Kay.

Mr. GAVIN KAY, Plumber, 81 Rotten Row, Glasgow, examined.

191. I had prepared the following paper to lay it before the Town Council of Glasgow; and as it contains my views on this matter, I shall just read it to you:—

'In laying before you my plan and system of purifying the common sewers of this city, I beg to state that, by practical experience on a small scale, I have for many years practically known it. I will show you, I think, its efficiency and durability; and as my system differs from others you have got, I crave your particular attention while explaining it, as I have no model, it not being necessary, and a written statement will do as well.

'My system is to alone purify the sewers, then, as a matter of course, the river is purified. No man can make the river pure till the sewers are purified. If one sewer, the worst in the city, is granted to me, I will make it the model for the whole city. That one sewer might be the one emptying itself into the river at Albert Bridge, which is conducted up the Saltmarket and High Street, how far I cannot say, but the ground plans will show. On this sewer there are many surface drains on both sides of the sewer, going into small streets, wynds and closes, back courts, vennels, etc. etc. These drains have on them open iron grates to carry off the surface water. The sewers become full of poisonous gases, especially during the night while people are in bed, and the foul air going up these drains all night into the lungs, becomes a fearful cause of disease, particularly in the low part of the city, where there are so many infants and young and sickly persons huddled together. This is the state of matters just now, and these drains damage every part of the city.

'To proceed with one common sewer, my system is that all these grates or surface drains and iron urinals shall be taken out, and in their place proper bell-traps put; they keep out both foul air and rats from getting into houses. Also all surface openings, such as lamps and outlets, shall be closed up. These bell-traps being put on that one sewer, and urinals, etc., I proceed to talk of the sewer. Cut down a sufficiently large opening to the top of the sewer, and opposite the newest house; at the top a track shall be cut from the sewer to the foundation of the house under the pavement, with a declivity down to the sewer, as shown by a simple sketch or plan which I now produce. In it shall be put an air syphon of large dimensions. If the sewer be a long one, it may require two. These underground syphons shall be fire-clay of the best material, well burnt and glazed. The upright fixed to the house, raglen corner, front of house, or gable. It shall be made of strong galvanized iron tube, rivetted on seam with white lead, having four coats of oil-paint all dry, and shall go up on said house 3 feet at least, or more, above the highest chimney-can on that building. These air-syphons, with bell-traps on drains, will cleanse the sewer in a few days, and keep it in all time coming free from poisonous gases—clean as when first constructed; and then no fear for the people. These air-syphons get hold of the foul air and noxious gases, and sweep all aloft into the atmosphere—like smoke from a vent—where its effects are dissipated. The sewers cannot be purified effectively without shutting all air in, in every quarter, by bell-traps on the surface drains and urinals, so as to throw all into the sewers, in order that the air syphons get hold of the poisonous gases. I know, also, the air-syphon sucks and draws and discharges aloft the effluvia, even from the mouth of the sewer at the river, then fills the sewer with pure air, night and day, year after year, without stopping, unless the house that supports the upright iron tube falls with age.

'In order to have my system as intended, I may suggest that there is in the north-east end of the city, by St. Rollox, that ground being high and having a great fall to the west; in my opinion there might be worse money spent than by making a large common sewer in that quarter by the north back of the city, and to empty a little below Kelvinhaugh. That sewer would be a great blessing to the city. At present, where the sewerage is let down, it is often almost insupportable. I had some years' experience of it in my house in Duke Street. This suggested sewer and drains must have bell-traps and air-syphons like the others in the city.

'As the air-syphons lift all the foul air from the sewers, it removes the offensiveness from the ordure or manure as it rolls down to the river, producing solidity, and so it falls to the bottom free from pollution. With regard to the river, you are aware it is a constantly running water, not a standing loch or pool, where all that goes into it tends to pollute it. Nothing of the kind, but the pollution that is flowing on the surface of the water comes from the sewers. When the tide is full, it is often about three-fourths of an inch thick; it sticks fast to the sides of rivers, ship-bottoms, logs, etc. These poisonous gases, when the tide recedes, dry, then fly ashore among the people. This is the case just now, but my system, by the use of the bell-traps and syphons, will prevent all pollution of the river. The substance or manure, freed from its noisome properties, sinks to the bottom of the river, where it is ready for the dredging machine. Besides, the river can be

deepened in the centre for what is solid. So the syphons, along with bell-traps, will prevent that poisonous gas floating on the surface of the river. Thus the surface being made clean, and the weir removed, the mills higher up the river will have plenty of clean water by a lade from the side of the river. Pollution then will become unknown.

'With regard to water-closets, in my opinion it were well if there were hundreds more in Glasgow than there are. All know their value, and when properly put up there is not a more cleanly and useful piece of furniture can be had. How to prevent any disadvantage resulting from their use, I can explain satisfactorily by plans and working drawings.

'Also, there is a cause of pollution arising continually, especially in the low parts of the city, occasioned by the number of houses of accommodation in a very disagreeable state, and when cleaned at night a noxious vapour is diffused in their vicinity. So if, instead of these, there were, although fewer, iron houses on the water-closet principle, with eight seats in each, and a urinal at each end, it would keep people from using closes and causing annoyance.

'To repeat, my system will keep the sewers clean, as if newly built, from all that is most offensive and dangerous. The manure and sludge running down amongst pure air, which neutralizes the nastiness of it, is discharged into the river deprived of its evil qualities, and the bad air flies up into the syphon, and is so conveyed away. Also the soil from water-closets is not defilement; any bad air coming from it the air-syphons take away, and the ordure, comparatively clean, then falls into the river, where, reclaimed by dredging, it will be found a rich and fertilizing manure. In regard to the noxious stuff accumulating in chemical works, such as oil of vitriol and the like, it should not be put down the drains upon any account, or in the sewers, until it be filtered in coarse sand and lime, so as not to cause pollution. This can be done at the tanks which contain it, and at the works.

'Such is my system for deodorizing the sewers and purifying the river, and if it is adopted, I believe it will prove a blessing to thousands. I might have written more in explanation, but not to take up your time I have omitted naming some most essential improvements for purifying the surface (in the city); but I trust enough has been advanced to recommend my system to your attention, and I leave it in your hands to decide on its merits.

'This system is my own, and belongs to no person else.'

Mr. Thomas Biggar, Manufacturer, Dalry, Ayrshire, examined.

192. The witness read the following paper:—

'*Mode of converting Night-soil, etc., into concentrated portable manure, as practised at Bridgend Mills, Dalry.*

'There are upwards of 600 hands employed at the works, and the whole of the night-soil and urine is now collected and converted into portable manure. The closet in use is what is known as the "air-closet," invented by the late Mr. Colquhoun, Paisley. As this closet is indispensable to the success of the method, it will require to be noticed first. The body of the closet is a square wooden box, inside of which is secured an earthenware tub, with a hole at bottom, to which a pipe is fixed, to convey the urine to a convenient receptacle. Inside of the earthenware tub is placed a moveable galvanized iron pan, with a perforated bottom, for receiving the excrements; at the back of the wooden box a three-inch pipe is inserted, which communicates with the boiler or other flue or ventilator. As outside air can only enter downwards through the seat opening, a downwards draught is established which carries every vestige of smell onwards to the flue and up the chimney stalk, where it cannot possibly annoy any one. Having noticed the closets, the method of dealing with the night-soil falls to be described. Every Saturday afternoon, as soon as the works have stopped, it is the duty of two men to open each of the closets, and after covering the pan with a suitable lid, to remove it, and substitute an empty one in its place. In order to allow the urine to filter away, a thin layer of one-half inch bones is placed in the bottom of each of the pans. The two full pans are placed on a low three-wheeled carriage, and drawn to the manure mill, where they are emptied. The manure mill is a circular tank of cast iron lined with brick and cemented. It is 4½ feet in diameter, and 3 feet deep, and is provided with a stirring apparatus driven by machinery. The mill is so arranged that the heated air and smoke from one of the fires can be made to enter at one side (immediately below the cover), and pass out at the other. On Monday morning, as soon as the fires are kindled, a quantity of sulphuric acid is added to the night-soil and bones, the heated air is made to pass over above them, and the stirrer is set in motion. The combined result is that the bones are gradually dissolved, the moisture is dried up, the night-soil is partially deodorized, and all smell evolved is carried up the chimney stalk. By Tuesday morning, if the heat is well kept up, the contents of the mill will have the appearance of a dark pasty magma, and the greater portion of the smell will have disappeared. Two hundredweight of good ground bone ash must now be put in, and well stirred, and there should be sufficient free acid remaining to dissolve the greater part of it. By the afternoon the manure will be sufficiently dry to be lifted out and taken to the manure shed. The bones and bone ash are useful in various ways. As before stated, the ½-inch bones allow the urine to filter away, so that it can be collected separately; 2d, they neutralize the sulphuric acid, which it is found advantageous to use in order to deodorize the night-soil; 3d, the sulphate of lime formed combines with part of the moisture; 4th, the night-soil is easier handled; 5th, they themselves form a valuable manure when dissolved. As soon as the mill is empty the urine is put into it, and after neutralizing the free ammonia with sulphuric acid, the heat is turned on, the stirrer gently moved round, and by Saturday the most of the moisture will have become dried up. Recently an evaporating receptacle has been built in connection with another flue, by which about one-half of the urine will be dried up without any trouble whatever, beyond that of taking out the dried contents once every six months. The dried urine is at present mixed with the other manure, and tends to enhance its value. During the last twelve months there have been made about 20 tons of manure, and it is being sold at £8 per ton. The following analysis shows that it is full value for the money:

Thomas Biggar.

'Biphosphate of lime, . . .	13·46
Equal to soluble phosphate (21·08).	
Insoluble phosphate, . . .	19·42
Sulphate of lime, . . .	19·82
Sand, ...	4·87
Alkaline salts, ...	2·35
Organic matter and water, . .	40·08
	100·00
Ammonia in organic matter, . .	2·75

After making allowance for bones, bone ash, sulphuric acid, labour, and power, a fair sum remains for profit. The advantages of the system are—1st, freedom from smell in the closets, as well as in subsequent process of drying; 2d, comparative ease of collection; and 3d, the production of a manure which pays.

'The system seems well adapted to large public works, because there the conditions needed to secure the greatest results are generally present. The conditions are a large number of people on a limited area, waste heat, and a tall chimney stalk. After the necessary plant has been obtained, the labour is small, and the sale for the manure certain. In looking at the above results, it must be remembered that the hands

Thomas Biggar.

are only present at the works about ten hours in the day, and not more than fifty weeks in the year. Although less likely to pay well, the system might be extended so as to meet the requirements of a large city, with great advantage in a sanitary point of view, and with at least a reasonable hope of profit. Let the city be divided into districts of a suitable size, at the lowest level of any district, or as near it as it is possible to obtain ground; let a long covered tank be built, with a furnace at one end and a tall chimney stalk at the other. The tank would be required to receive the urine produced in the district, and the heated air from the furnace fire would effect the double purpose of drying the urine and maintaining a draught for the closets. Every tenement would of course have to be provided with a "Colquhoun closet." From each closet a 3-inch air-pipe would require to communicate with a main-pipe laid along the street. The main-pipes of the district would all converge into a space below the fire-bars of the central furnace. The deleterious gases from the closets would thus be drawn to and pass through the fire in the furnace, when they would become thoroughly decomposed, and afterwards pass up the chimney stalk. The fire might be allowed to go out at stated seasons, in order to remove the dried urine. If this was done at night the ventilation of the closets would not be interfered with. The dried urine might either be sold in that state or mixed with the night-soil manure. Another system of pipes would require to run alongside the air-pipes in order to convey the urine into the evaporating tank. The main-pipes in both cases might be of fire-clay well cemented at the joints. At some central and, if possible, elevated situation, as far as possible from dwellings, a manure factory would have to be erected where the whole night-soil of the city would be collected and made into portable manure. The apparatus needed and the plan of working would be very similar to that in use at Bridgend Mills, but of course on a very much larger scale. As a steam-engine would be required to drive the stirring and other machinery, one or more steam-boilers would be needed. The waste heat from these would dry or assist in drying the night-soil, and the smoke, etc., would pass as usual up a tall chimney stalk. A staff of men with horses and covered lorries would be employed in removing full pans, and leaving empty ones in their places. These labours would be performed from very early morning till say 7 or 8 o'clock A.M. As one pan would serve an ordinary family two or three weeks, and in many cases longer, this staff of men and horses need not be so large as one at first sight would be led to suppose.

'Such are the salient points of a plan for applying the system to a large town or city which suggest themselves, after two years' experience of it on a less extended scale.

'BRIDGEND WORKS, DALRY,
'*March* 23*d*, 1875.'

193. Can you give me any idea of the cost of what you have been describing as applied to your own mill?—We sell it at £8, and I think the cost would be about £5 to £5, 10s.

194. But I mean the cost of the apparatus. Can you give me, in round numbers, about what it cost you to start this process in your mill?—It does not cost very much. Each closet would cost about £6, and then there are the pipes connecting with the chimney. I should think that the whole thing would not cost us more than £100 or £120.

195. I suppose I may take it that the whole cost would not exceed £150?—I am certain it will not exceed that for our 600 workers. I have brought a small quantity of the manure in order to show it to you.

196. I should like to see it, but in the meantime you consider that the cost will not exceed £150, and you think that the after process that you carry on really costs you nothing, as the price you get for the manure covers the expense?—It will more than cover that now, and we make a considerable profit out of it. I think all that we put into it will not cost us above £5 or £6, and we get £8 for it. I think we have about £2 per ton of profit. I have a small mill for grinding the manure, and it is sown on the grass just like guano. (The witness produced a specimen of the manure.)

197. I understand that at your mills you also apply some method of purification for the woollen manufactures?—Yes. I have written a short account of it, which I shall read. I have not carried the account of it further than the point where it is prepared for distillation. We distil it as well, but I have not gone into that, as I understand you only wish to have it up to the point when it would be put into the river.

198. Yes. I merely wish to get it up to the point when you render the water to be put into the river innocuous.—The witness then read the following statement:—

'*Treatment of spent Soap-suds practised at Bridgend Mills, Dalry.*

'The above-named works are situated on the river Garnock, a fishing river; and it became necessary, for the protection of the fishings, to adopt some plan to neutralize the spent soap-suds, so that the water returned to the river might be clear and innocuous. The spent soap-suds are produced in the scouring of wool, and contain a certain percentage of the alkali used in the process of scouring, tallow or oil, which is present in the soap required, and also the animal grease and other impurities present in the wool previous to scouring, as a large proportion of the wool used at these works consists of blackfaced laid wool, that is, a wool which has been treated while on the sheep's back with a salve composed of butter (or some other greasy material) and wood tar. The result is, that the suds, when run out of the wool-washing machines, are very impure, and very destructive to fish, and from their nature do not amalgamate with the water in the stream, the oily or fatty matter floating on the surface, and the earthy material remaining for a considerable time suspended in the water.

'The means adopted to render the spent soap-suds innocuous, and to clarify the greater part of them, so that the water may run into the river again, is as follows:—The spent suds are conveyed by pipes into brick tanks, and there treated with a certain quantity of sulphuric acid, and it has been found that the most economical acid is of the strength of 144 degrees (Twaddle). The tanks used contain each from 2000 to 3000 gallons of suds. After being filled with suds the acid is added, and the contents of the tank are then briskly stirred with a wooden plunger for a short time. When the acid is put in a considerable effervescence takes place, caused by the action of the acid on the alkali. The result is the neutralizing of the alkali by the acid, and the setting free of the fatty matters formerly held in combination with the alkali. The tank is then allowed to settle for about eight hours, after which it is found that a certain portion of the lighter solid matter has floated to the top, and the heavier portion has settled to the bottom of tank, the clear water lying in the middle. This water, which then contains a weak solution of a soluble salt (sulphate of soda), is tapped off and allowed to flow into the river; and to facilitate the tapping off the water, the tank is constructed with a thick hard-wood board, perforated with holes of about an inch diameter, built into the brick-work of one of the ends of the tank, or in the most convenient position for running off the water. The holes in the board are filled with wooden plugs when the tank is filling, and one or more plugs can be taken out at pleasure when running off the water. When the water has been run off, the residuum is left at the bottom of the tank, and is of the consistency of a thick cream, and of a light-brownish colour. This residuum is then pumped out of the tank and allowed to spread over a filter-bed, composed of gravel and a layer of sawdust on the top, and the water in it is allowed to filter away, and the material then becomes of the consistency of soft clay, and is termed "magma." The grease is afterwards, by steam-heat and pressure,

extracted from the magma, and the earthy impurities, which still contain a small portion of grease, are used, mixed with coal, as fuel. The grease recovered is by other processes converted into stearine and cloth oil; but as these processes are another branch of manufacture, they are not here entered upon.'

199. Can you give me any estimate, in round numbers, of the cost of this process applied to a woollen mill? What do you suppose those tanks would cost?—The erection of the tanks would not cost a great deal. I think it would not cost above £50 or £60. They are just brick tanks.

200. You mean that all that you require for this process is to get off the greasy matter?—Yes. You require a tank, and then you run it into the tank; and we adopt the plan of a board at the side. If you put the cost at £100, you will be quite safe. It does not take up much space. Just now we have no complaints whatever about the water injuring the fish. The colour of the water when run off is like that of brandy.

201. Does it satisfy the people below you now?—Yes; they are quite satisfied. That was all tested and proven years ago, when they got it analyzed.

202. Do fish live in it?—Yes; they do so now. The right of fishing in the river belongs to a gentleman in the neighbourhood, Captain Blair, who has an old charter from the Crown; and he let it to a party of gentlemen from Glasgow, who complained that we killed the fish. We had a law process about that, but now they are satisfied.

203. By the time you finish this process and convert the material into stearine, does that pay the expenses?—I found it did not pay to sell it in the rough state; but I now find it to pay because I carry it further on, and I put it into oil and stearine now.

204. And by making it into oil and stearine you consider that the process pays for itself?—It certainly does. We have stills, and we distil it as well by superheated steam. We superheat the steam up to about 600 or 700 degrees of heat. The stuff changes its colour. It is quite a black colour at first, and it comes out of the stills nearly white. By two distillations it is made almost as white as snow. The stearine must be white for making into candles. We sell it for candles, and they also mix it with paraffin.

205. Then I gather from what you have read and from what you have now stated, that supposing there was no better process, it would not be a hardship upon works like yours, with 600 hands, to require them, in the first instance, to deal with their privies in the way you have just been describing. Would it be a hardship to a woollen mill to require it to deal with the other matters in the same way?—No; they could easily do it, if they would only be at a little trouble and expense,—that is, so far as regards the scourings of wool; I cannot speak about any other thing.

206. I am speaking only of a woollen mill.—They could very easily do that; there is no doubt about it.

207. What space does the process for dealing with the soap-suds take up?—The tanks are about 15 feet long by about 3½ feet wide.

208. How many are there of them?—Three. They hold about 2800 gallons each, and we fill one of these every day. Then we have long filter-beds, about 40 feet in length and about 6 or 7 feet in width.

209. How many filter-beds have you?—We have five filter-beds.

Provost MURRAY, Paisley, examined.

210. I may premise, Sir John, that I do not come here to advocate any theory or to propound any scheme of my own for your consideration in this important inquiry; but as the town which I have the honour to represent here before you to-day is very much interested in your inquiry, I thought it right, before you made up any report, that you should be put in possession of some information with regard to the state of the town of Paisley, as regards public works and the impurities which flow into the river Cart, a tributary of the Clyde. The population of the town, as I have no doubt you are aware, may be stated roughly at about 50,000. It is situated on both banks of the Cart, and the population are very largely employed in manufactures of various kinds. I may mention that besides smaller industries, such as handloom weaving, there are 23 dye works, 5 soap works, 8 starch and corn-flour manufactories, 8 scouring and finishing works (that is, for scouring and finishing cloths and yarns), 1 brewery, 1 distillery, 1 paper work, 10 thread works, 2 carpet works, 3 chemical works, 1 tan work, 1 oil work, 7 engineering shops, 1 powerloom factory, 1 foundry, 3 bleach works, and 1 candle work; and that 9 various processes, more or less, throw impurities into the river. 37 of these public works discharge their waste outfall direct into the river Cart; 18 into a burn called the Espidair burn; and 7 into another burn, called St. Mirren's; and these streams all fall into the Cart as it passes through the town. There are also 23 other works that discharge their impurities into sewers; and these sewers, with one exception, all find their way into the river, also at the town. The total amount of waste outfall discharged daily from these various works, exclusive of rainfall, I estimate as follows:— *Provost Murray.*

Dye works,	364,420 gallons.
Soap works,	6,130 ,,
Starch works,	117,600 ,,
Scouring and finishing works,	299,725 ,,
Brewery,	12,000 ,,
Distillery,	20,000 ,,
Bleach works,	67,280 ,,
Oil works,	6,000 ,,
Smaller works, about	25,650 ,,
In all, about	918,805 ,,

It is right to mention, with reference to this matter, that 10 of these works have settling-tanks, and I have no doubt these prevent a good deal of impurity from reaching the river, which would otherwise find its way there. Indeed one of these works—a starch work—has no fewer than 7 of these depositing-tanks, and the water from it passes off comparatively pure compared with the water from the others that have no such tanks. So far as I can gather, and I think I am rather within than over the mark, there are 360 water-closets which find their way into the river. The town is very imperfectly and but very partially drained, and not on any general system. Plans for a general system of sewerage were obtained many years ago, but these plans contemplated the disposal of the sewage by irrigation, and it was found that the soil into which that irrigating process would go was not suited for the purpose, being a heavy clay stiff soil below. That consideration, as well as the unsolved problem about the disposal of sewage, has hitherto prevented the local authorities from incurring the expense of carrying out that general scheme. I need not trouble you, Sir John, with the details of the partial drains that we have, because I believe our Master of Works has sent you a copy of the Ordnance map, on which the existing drains are indicated, such as they are. In addition to the impurities that flow into our river from the works situated within the Parliamentary limits, there is a large amount of impurity that comes down to us from works situated on the upper reaches of the river, and tributary streams falling into the river above the town. The course of the river Cart, as you will see from the map, flows through the parishes of Eaglesham, Mearns, Cathcart, and Eastwood, and all along that extensive stretch there are large numbers of public works, such as bleach works, paper works, printing works, dye and chemical works of various descriptions, from which a large quantity of impurity finds its way down into the river. In its course through the parish of Cathcart the river Cart receives part of the sewage of the suburb of Crosshill, about which so much has been said lately

Provost Murray.

in Parliament; and in passing through the parish of Eastwood, it intersects the town of Pollokshaws, in which, I believe, there is a paper work, and a number of other works, which discharge into the stream, in addition to any general sewage from that manufacturing town which falls into the river. Besides the pollution which flows into the river where it passes through the town, and also into its upper reaches, there is a stream called the Levern which intersects the extensive valley of Neilston and Barrhead, Hurlet and Nitshill; and along it there is not only an extensive population all engaged in manufactures of one kind or another, but there are manufactories which throw a great deal of pollution into the river, so that, in addition to what falls into it from the town of Paisley itself, its manufactures and its sewage, there is a large amount of impurity that comes down from the villages and works situated on the upper reaches of the river. The impurities in the river Cart, and so far as these impurities find their way to the river Clyde, are, I think, mainly attributable to public works. The sewage of the town does not, in consequence of the defective sewerage, pollute the river very much. The best proof of that is, that on Sundays, and on other days when the public works are not on, the difference between the flow of the water and its purity then, and on other days when the works are in full operation, is very marked indeed. I am not insensible to the advantage of having a system of drainage, but I repeat that I think the impurities which affect our river, and which may find their way from our river to the Clyde, are mainly attributable at present to the public works. Of course the purification of the river Cart or the river Clyde means really the disposal of the sewage, and of the impurities that are now finding their way into it; and, of course, I don't know what Glasgow, or Paisley, or other towns would be without their public works, giving employment and remuneration to artisans, and giving wealth to the capitalist; and I should not like to say anything that would injure public works or drive them away; but I am afraid the days of pure rivers, such as we have been accustomed to see, are at an end. At the same time I believe that, as with the smoke nuisance, a very great deal can be done to mitigate and reduce, almost to a minimum, the complaints against the offensive matter that is thrown into the streams. I listened to the gentleman who preceded me, and who satisfied me, as I have been satisfied before from knowing what has been done in some other works, that a very great deal can be done by deposition and filtration, and the application of chemicals, to render comparatively innocuous much of the offensive matter that now finds its way into the rivers from manufactories and other works. In so far as the town of Paisley is concerned, I am afraid that the water-closet system will never be applicable to remove the human excreta, and that because we have so large a portion of our population belonging to the industrial classes, and living in tenements to which water-closets are wholly unsuitable; but I think that if some stringent police regulations were adopted, enforcing either dry earth-closets, or probably something simpler still, the construction of dung-hills and common privies, on such a principle that the ashes would fall into them and deodorize the human excreta, and, by a considerable addition to the police expenditure, removing these very frequently, and enforcing cleanliness in the back courts, much might be done to mitigate the evil. I may say that what has been described to you by Mr. Biggar has been carried on in some of our large public works by the use of the earth-closets, which he described; and I believe that some of Colquhoun's closets are in operation in one or two of our largest factories; and also another by a Mr. Moser, of Southampton, has been in use in some of our schools, and has been found most efficient. I had seen it in operation myself in some of the workhouses in England, and I got it introduced into our industrial school. I shall send you Moser's description of it. It is a very simple self-acting thing, and seems to answer admirably. I believe that the enforcing of some such system on all public works and public institutions and schools, where large numbers of people are congregated together, would reduce very largely the amount of the impurities which are at present thrown into our drains. As I have already said, I have no theory to propound; but I believe that, even with such a system as I have mentioned, it would be necessary that we should have some system of drainage to carry away house slops and waste water, and all that accumulation which necessarily takes place in every community where human beings are congregated together. The disposal of that seems to me at present, so far as I am able to judge, to hinge very much upon two modes,—either carrying it away by some expensive engineering process and throwing it into the sea, or so using it in the neighbourhood of the town, by deposition and filtration, as that the circumambient water may be allowed to flow, if not perfectly pure, at least in such a state as would be innocuous to health. I confess my present opinion seems to tend to the latter scheme as being the least expensive, if it can be carried out; but upon that matter I have great hesitation in venturing an opinion, not being a practical man. I don't know that I have anything more to say, but I wished, before you make up any report, that you should know the exact state of our locality.

211. You spoke of one large work, I think you said it was a starch work, that had got reservoirs: can you give me any notion of the area which they occupy?—No; but I shall send in a note of it. I could not speak at present about their size with any accuracy, because I have merely looked at them.

212. With regard to the works generally which you have been describing, have they in most cases any spare land upon which they could provide tanks or settling places?—Many of them have; but I am sorry to say also that, in some instances, in the centre of the town, where land is expensive, and where works have been set down without the means of extension, it might be a little difficult to provide such accommodation.

213. That is a thing which would have to be considered; because, suppose we were to come to the conclusion that we ought to require all these works to do something or other in order to purify their refuse, there might be some cases where it would be difficult for them to get space?—Yes. I may mention that when the Rivers' Pollution Commission was here, the chemical member of the Commission gave it as his opinion that the refuse from the starch works and distilleries was of all the refuse the most deleterious, but was, at the same time, the refuse which would be most easily collected, and be most valuable. I may say also that, although hurting the river so far as fish are concerned, and also hurting the appearance of the river, I am not sure that the dye-stuffs which are put in produce any very prejudicial effect upon the health of the inhabitants. From the acids and alkalies in them, although, when thrown into the river, they tend to blacken it and destroy its beauty, yet at the same time they tend to destroy some of the other deleterious ingredients that come in from other works.

214. How far was the land from Paisley on which you say it was proposed to put the sewage, and which you say was unsuitable?—It lies to the north of the town. It was originally a moss or morass, which had been drained. It was a light soil on the top of a very heavy clay.

215. Have you any light sand-soil near Paisley?—None.

216. Have you none within any moderate distance?—No. I am afraid we have nothing nearer than the coast.

217. You heard Mr. Biggar's evidence?—Yes; and I happen to know Mr. Biggar personally.

218. From what he said it did not seem that there would be any great hardship in requiring a large work to provide for its excreta in the way he mentioned. What is your opinion about that?—I can see no difficulty in doing that in the case of a work, but I have some doubts how far it would pay to apply it to a large town.

219. That is quite another question. I am only dealing with works in the meantime.—I would go in for enforcing some such scheme as that upon every public work.

220. Its application to large towns is, of course, quite another question. I was only looking at its application to works, and where you have so many works in a district as there are here, it would be very important to get some means of taking away that portion of the sewage.—It would; and some scheme of that sort would take away a great quantity of the sewage, because there are so many people congregated about these works for more than half the day.

221. In the new fortifications, which have been building so extensively in England within the last few years, provision has generally been made for the use of earth-closets; but that is easily managed in a fort, because soldiers are under discipline, and you can make them do as they are told, but even in works it appears there is no difficulty in making regulations for the use of such places, and seeing that they are observed.—That is so; and I believe that if these common tenements, where so many people reside, were under more strict police surveillance, and the ashpits and dung-heaps were constructed so that they might be cleaned out once a week, the ashes would fall and cover the excreta in such a way that it could be easily removed. That would involve some expense and some surveillance on the part of the local authorities, but I am certain very much could be done in that way to lessen the nuisance among that class of people to whom water-closets can never be applicable, because they would not remain in working operation for eight days.

Mr. Malcolm Macdonald, Crosshill, examined.

Malcolm Macdonald.

222. I would propose to dispose of the sewage on Mr. Bateman's plan,—taking it down the river; but instead of leading it into the river, I would, at convenient distances, erect basins that would contain one day's sewage, and the railway could convey the ashes of the city and drop them into these basins. What I may call No. 1 basin would have, say, this day's sewage, and then next day's ashes would be taken and dropped into the basin. Another basin might be made at a convenient distance from the first, so that while the first was being filled with ashes the second would be filled with sewage; then while the second was being filled with ashes, the third would be filling with sewage. The solid matter of the sewage and the ashes would assimilate to each other in the basin No. 1, and there could be a sluice from it, with probably a filter attached to it, so that the water or fluid matter that was on the top would go into the filter and be filtered away; and in process of time the stuff in the first filter would become very good manure for boggy land. Another way would be, that a pipe might be conveyed from the tank No. 1 to a lower level, in order to serve for irrigating purposes farther down. Experience would show the distance at which each basin should be made from another, but that gives an idea of what I propose. Basin No. 1 would be filled with sewage and then get its quantity of ashes; and basin No. 2 would be getting filled with sewage while No. 1 was settling down, and, after getting its sewage, basin No. 2 would be filled with ashes; then basin No. 3 would be getting filled up, and ashes would be conveyed to it while No. 2 was settling down; and while No. 3 was filling, the solid matter in No. 1, having gravitated to the bottom, might be removed. In that way the farmers in the neighbourhood could get their manure from a place near their farms instead of having to drive it from Glasgow. The scheme which I have now proposed has reference to the north side of the river. The same plan might be adopted on the south side, and in that case Paisley might be taken in, and Johnstone, and all the towns farther down. That would be an important matter, because the purification of the Cart is an element in the purification of the Clyde. There is no machinery necessary for the scheme which I have proposed, and no chemical processes. There would be no expense in that way. The thing would work in the simplest manner; and I think it would be the least expensive of any, and the most easily done.

223. I quite understand your proposition; but, of course, you would have the expense of conveying the ashes to each receptacle?—It would not cost much to have a truck filled with ashes and taken down to one of these basins; but if the sewage was converted into manure elsewhere, it would require to be conveyed in trucks to the country districts at any rate. The ashes might be filled into trucks, and a railway siding might be laid into the basins, and the ashes emptied into them in that way. If this plan were adopted, the stuff from our Glasgow conveniences, instead of being put into pans and carted through the streets, might be run into the sewers. Another remark I may make is, that in the eastern districts of the town, the ashpits are closed in at the top, which I think is a great blunder. I should propose that the conveniences should be erected at a wall between the different buildings, and that the ashes should be put in on each side, and that the top should be open in order to let in the air of heaven, and to have free ventilation. When these conveniences are closed, as our city ashpits are at present, then what is thrown into them is simply concentrated; whereas if it had free play, the air would be made wholesomer, and people would be less liable to suffer from infection. That is simply an idea of my own. I don't know whether I am correct in it or not, but I have frequently observed, in country places where I have been, and where these places are made more close, that the smell from the conveniences is very noisome. It catches one whenever you go near it. Our city places are more open, but some of them are as bad as those that I have seen in the country.

224. Is there anything more you wish to add?—Nothing, unless you wish to put any questions to me. I may say that my plan would include Paisley, and all the other towns in the neighbourhood, because there would be a separate scheme for the sewage on the south side of the river.

Dr. Andrew Fergus, M.R.C.S. Eng., President of the Faculty of Physicians and Surgeons, Glasgow, examined.

Andrew Fergus.

225. I was district surgeon, for nearly twenty years, of a district of the city extending from a central line between Washington Street and M'Alpine Street on the west, to the central line of Dunlop Street on the east, and from the central line of the river on the south to Argyle Street on the north; and I wish, in the first place, to speak about my experience there. During that time, I did not find any prevalence of excremental-pollution diseases in the district.

226. At what period were you district surgeon there?—I think it would be from about 1847 to 1866; and during that period I never found that the polluted state of the river had any effect whatever upon the public health. I took particular notice, for another purpose, of the prevalence of an epidemic of cholera in 1854; and I found that during that epidemic, along the whole line of the Broomielaw, including all the shipping, from Washington Street to Dunlop Street, where some of the courts contain a very large population, there were only twenty-one cases of cholera and eleven cases of diarrhœa. I mentioned, however, that the west boundary of my district was the centre of the space between Washington Street and M'Alpine Street, in fact, the boundary-line was a sewer which had formerly been a burn; and I considered that that sewer produced a very deleterious effect indeed, because in that one street, M'Alpine Street, not by any means a very populous street, running from Argyle Street to

Andrew Fergus.

the river, I had during the same period seventy-one cases of cholera and forty-six cases of diarrhœa. I may mention, as a remarkable fact, that as you receded from the sewer so did the cases of cholera diminish. These observations were all made before I paid much attention to excremental pollution as a cause of disease; but since then I have been turning my attention a good deal to that matter, and specially since the introduction of the Loch Katrine water, because, if we have excremental pollution as a cause of disease, it must be conveyed either by air or by water. Now, as regards water, I think Glasgow is beyond suspicion; because, as you are aware, the public wells have been absolutely closed; and therefore, if we have excremental-pollution diseases in Glasgow, unless they are conveyed by milk, which is a factor in the conveyance of these diseases, it must be through the air. With regard to typhoid fever, it was not kept separate from typhus until the year 1865; but since 1865 we have had an average of 195 deaths a year, and an average of 26 deaths registered as infantile-remittent fever, which in my impression is much the same disease; and if you put these together, you will find it gives an average of 49 deaths per 100,000 people living. That led me to look to other places; and I found, on looking at the reports of Mr. Simon, the medical officer of the Local Government Board, and formerly of the Privy Council, that, according to one of his former reports, there were 60 places visited by his inspectors on account of their increased death-rate, and that increased death-rate was produced in 50 of these places by excremental pollution, producing in 49 cases typhoid, and in 16 cases scarlet fever. From his last report, I make out that there were 138 places visited on account of increased death-rate; and in these, typhoid fever existed in 127 places, diarrhœa in 21 places, and scarlet fever in 19 places. With regard to the influence of water-carriage, that is to say, water-carriage introduced into workmen's houses, I may read a quotation from what was said by Dr. Littlejohn, the medical officer of health for Edinburgh:—'If they took a range of houses where this had been done (that is, where water-closets had been introduced), in the course of one year there were double the number of deaths from typhoid and scarlet fever; and any epidemic fever occurring in these houses was intensified, and assumed a character of malignant mortality.' In connection with this subject, I was at the trouble to prepare a table from the returns of the Registrar-General from 1838 to 1871. There is a hiatus from 1842 to 1847, as no returns were procurable for these years. I wanted to find out exactly what was the state of the public health as regards excremental-pollution diseases and other diseases, and I got the table checked, and the percentages worked out, by a gentleman used to these things. That table is contained in my pamphlet on *The Sewage Question*, a copy of which I shall hand in. I find from it that from 1838 to 1842 there was an average of diarrhœal deaths, per million of people living, of 298; during the five years from 1847 to 1851 (including an epidemic of cholera), there was an average of 1569. I need not go into details with regard to the whole period, but taking the last five years—1867 to 1871—when there was no such thing as cholera, the diarrhœal deaths averaged 1161 per million of the people living—that is to say, they were nearly four times what they had been in the five years from 1838 to 1842. Then, taking another disease, there was not a single case of diphtheria registered until 1851, and then it is debited with 2 deaths per million of the people living. By 1859 it had risen to 487 deaths per million of the people living. It is now down, but I have never since found it below 100. Then, as to scarlatina, I found the deaths from it in the first five years of the return to be 798 per million, and during the last five years, 1017. Unfortunately, at first the fevers were not separated—the typhus from the typhoid; and therefore I don't think the information with regard to them has much bearing; but I may mention that during the first five years the number of deaths from fevers was 1053, and during the last five years, 800. The first three diseases in that table, I hold, can be excremental-pollution diseases. Then I come to the diseases that are not so clearly traceable to that source; and I find, with regard to measles, that during the first five years the mean was 540 per million of people living; and during the last five years, 409, being a decrease. Then I take hooping-cough, and I find that during the first five years there were 504 deaths, and during the last five years, 491, being a very small decrease. Small-pox, showing the influence of compulsory vaccination, gave 577 deaths during the first five years, and 283 during the last five years. Then, taking the totals, I find that during the first five years the total death-rate per million of people living was 22,078, and during the last five years, 22,341, being a slight increase; but if you go into detail, you find the whole increase taking place in the excremental-pollution group of diseases, and that in the other diseases there was absolutely a decrease. With regard to the diarrhœal group of diseases, Dr. Greenhow says, and Mr. Simon confirms it, that they are on the increase, and that they can always be traceable to one of two distinct causes,—the taking into our system, by air or by water, organic matter in a state of decomposition, and most frequently human excrement. I mentioned decomposition just now, because I hold that fresh excrement is not in the least degree injurious to health. By the researches of Dr. Angus Smith, it has been well ascertained that the air in towns differs from the air in the country; that there is generally less oxygen in the air of towns, and that there is less in crowded districts than in open districts, and there is less in the neighbourhood of middensteads than in any other part. Therefore the decomposition of organic matter going on, as well, of course, as the breathing of animals, robs the air of a certain amount of oxygen, and in that way it will be injurious by lowering the health. But then, I think, that same decomposition going on will produce specific poisons, and it will increase enormously the infective power of any zymotic disease—that is to say, the infective power of the excremental discharges of cholera and diarrhœa, and of typhoid fever, will be enormously increased by the decomposition going on. Now I have said already that Glasgow should be free from excremental-pollution diseases; but unfortunately it is not, and the question is, What is the reason? I have said before that I think it is mostly to be found in the air. I have repeatedly, in cases where there was typhoid fever, found by examination that the pipes in the houses were defective. I now produce a specimen of one of these pipes, the history of which I shall give you; and one history will serve as a type of a great number. I was attending a case of typhoid in the house where this pipe was afterwards got. When I was called in, I asked the lady of the house if her closet arrangements were all right and proper. She happened, I suppose, to know something of my proclivities, and said, in a very triumphant manner, 'Oh, doctor, you are quite in the wrong this time; the whole closet was renewed two months ago.' Well, you can't argue with a lady, so I retreated; but two days afterwards, when I was again in the house, I said: 'Where does that smell come from?' She said, 'Oh, the plumber says it is a dead mouse, or a dead rat in the skirting!' I made the exclamation, 'A dead fiddle-stick! Go to the plumber and tell him that the soil-pipe, or the cross-pipe, is all decayed and eaten away!' She afterwards told me that the plumber was greatly astonished next day when he found the pipe just as I had said. I told her to make the plumber keep the pipe; but plumbers, we know, won't keep pipes generally. However, I went up to his workshop and said, 'I want that pipe;' and he said, 'You cannot have it.' I said, 'I don't want it as a gift, but I will pay you twice the price of old metal for it.' He said, 'Our people won't like that;' but at last I got the pipe, and I now show it to you. This (showing) is the upper surface, and you will see that it is all worn and eaten away, and that, as I think I will be able to prove, by the action of gases. It comes to be rather an important question in connection with this matter, how long lead pipes

will last, and I shall speak to that immediately; but the proof that this has been caused by gases is, in the first place, that it is the upper surface of the pipe or the sides of it that are eaten away, it is not the bottom of the pipe, where the water ran. You will find in the place where the water ran, that the pipe is as whole as on the day when it was put in. The next proof that the decay has been caused by gases is to be found in the chemical analysis. This white powdery stuff is mostly carbonate of lead. The next proof is, that the pipes will last much longer when they are open, or, as it is technically termed, ventilated, than when they are closed. I used to fancy that a non-ventilated pipe would last from eight to ten or twelve or fifteen years, and I used to say that a ventilated pipe would last from twenty to thirty years; but quite recently I cut out a pipe in my own house which had been open, and which had been only sixteen years in use, and I found that it was quite eaten away and decayed.

227. Was it ventilated?—It was ventilated. Before I go further, I should like to show you a plate in which there are representations of several of these decayed pipes. The upright pipe on the right-hand side of that plate, with the perforations in it, is a pipe which has been laid open to show where the water ran, and where the pipe was perfectly good. When I showed the decayed pipe, which I have now produced, to some gentlemen, I was told that that must be peculiar to Glasgow; but the fact is, that the worst pipe shown in that plate is one which came from Edinburgh, and only a few days ago I got some pipes from London which were even worse than any of these. Well, having observed these matters for a number of years, and satisfied myself, by chemical analysis, that these results were produced by gas, the question occurred to my mind, How did the gas get there? I observed that these perforations were always on the house side of the trap.

228. What do you mean by the house side of the trap?—Not the sewer side, but always in the house, or on the side next the house—that is to say, there was always the trap interposed between the decayed part and the sewer; and the question came to be, How did the gas get there to destroy these good, well-made lead pipes? Three things occurred to my mind as likely to be the cause; one was an occasional tension in the sewer overcoming the resistance of the trap, which, however, I did not think could be of much importance, for it was a thing which could only happen occasionally. The next thing that occurred to me was, that on the house side of the trap, as the fæces are generally lighter than the water, they will float, and can only get away when they partially decompose. That I thought might produce, and possibly it does produce, a certain amount of this gas, which causes the destruction; but afterwards another thing occurred to me. Remembering the late Professor Graham's experiments about the diffusibility of gases, I thought that the same law as regards diffusion might hold through water as through other media separating the gases from each other. Professor Graham's experiments were of this nature, that if you take a vessel filled with a very heavy gas, say carbonic acid 1·5, and a lighter gas, say hydrogen, by and by the two would commingle, and I thought that that diffusion of gases might take place through water. I performed a number of experiments in proof of that, of which I have the diagrams here. At first I tried ammonia, but the objection was brought to that, 'Oh, that was very likely to happen, because ammonia was much lighter than water;' but the very singular fact came out that ammonia, though a lighter gas, passing very rapidly away, first of all saturates the upper surface of the trap, and then sinks down in a fine stream, taking the upper curve of the trap, and—what was quite new to me, and I believe was new altogether—it appears to discharge here (showing on diagram) long before the body of the water is saturated, and in fifteen minutes it shows here (showing) the reaction, and in half an hour it shows by hanging up a piece of litmus paper here (showing). The objection was brought to this experiment that it was a light gas; and another objection was brought against the whole of the experiments—'But your trap is not ventilated.' In order to meet that objection I put in a ventilator here (showing on diagram), and I found that the result was exactly the same, only taking a little longer time. Well, the objection being taken to the light gas, I then took a heavy gas, carbonic acid, 50 per cent. heavier than the atmosphere; it still saturates the surface, but, being a heavy gas, sinks down by the broad curve of the trap, and shows in the usual way. Then I took sulphuretted hydrogen, also a heavy gas, and it passes right through the centre. Then here (showing) was a very interesting one, the heaviest of all gases, chlorine 2·50. It saturates the surface first, and, being a heavy gas, sinks down along the bottom. If this trap had been filled with litmus water, the whole colour would have been discharged in three-quarters of an hour. Therefore I conclude that the destructive action on these lead pipes is very likely produced by the diffusion of sewer air through the water in the trap. In these experiments the gas was always at a great disadvantage, for it was placed down here (showing) at a considerable distance from the water, and the bottom of the model trap was perfectly open, so that a heavy gas in the vessel did not rise above here (showing), and you would naturally fancy that it would just have flowed over and gone out at the bottom. The practical inference which I draw from these experiments is, that, so far as I am aware, no water trap will be sufficient to keep sewer air out of your houses. Then, with regard to water as a carrier of excremental matter, I must observe that it is simply a carrier. Water of itself and by itself has no power of self-purification. It simply removes the filthy matter, whatever it may be, from one position to another. I have used the expression, 'water of itself and by itself' has no purifying power. There is no doubt that running water has a considerable power to destroy excremental matter, but it is the air contained in the water that has that effect; that is to say, if you could by any possible chance shut up perfectly pure water and (if you can use the term) pure filth together without any air, it would remain filth still; it would not be purified. Now that, I think, is a fact of some importance, because, take the Clyde as an example, if you put in so much refuse organic matter up at Lanark, the water from there has a regular fall, it is continually being re-aerated, and by the time that it would reach Glasgow it would be almost free from that organic matter. But that would not hold if you put an enormous amount of organic matter into the river where the flow is very slow, such as at Glasgow. Then again the putrefaction, I think, is assisted by shutting up the organic matter in narrowish passages with a limited supply of air and water, and especially with heat; and the practical inference to be drawn from that is this, that steam or heated water should be as little as possible put into the sewers. I think another factor in producing decomposition is the fact of decomposition being there already; that is to say, that matter already in a state of decomposition acts, as it were, as a ferment, and causes the rapid decomposition of the added excremental matter. Generally drainage dries the sub-soil, and this is a sanitary benefit; but if water from the sub-soil can get into the sewers, polluted air, as the result of the decomposition, can get out of the sewers and pollute the ground. Then, again, I consider that sewers are very seldom self-cleansing. No doubt if you take the time that pure water will flow through sewers, they are so laid that if the substance was only pure water, they might be self-cleansing; but as the substance to be conveyed is not pure water, but is a mixture of numberless things, many of them specifically heavier than water, it then happens that there is a lodgement. I have been noticing sewers for a considerable time, and I have not found in any sewer, not even in a six-inch house drain, that there was not a deposit, while in larger drains there was a still greater deposit. In the small drains it is a mixture of sand and other matters from the household slops; but wherever a deposit takes

Andrew Fergus.

place, of course the flow will be retarded, and decomposition will be facilitated by organic matter lodging in the irregularities of the deposited surface. Now I think that sewage, when it is entirely in the open, is not injurious to health, although it is certainly extremely offensive, and it is very desirable to get quit of it. I have also the opinion that an enormous deal of the pollution of our rivers arises from organic matter, and chiefly from human excrement. I think the best proof that can be given of that is shortly to compare three rivers. On the Thames there was no very great increase of chemical works, but an Act was passed in 1847, and confirmed in 1851, compelling all human refuse to be thrown into the river; and we know how rapidly the river stank. On the Tyne, again, I was utterly surprised at what I learned a few years ago. I then believed that chemicals had a good deal to do with the pollution; but knowing the enormous amount of chemical refuse that went into the Tyne—45 per cent. of all the alkali is produced on the Tyne—I yet found salmon passing up freely. Dr. Angus Smith told me that the refuse from those works was put into the Tyne in a much more acid state than anywhere else; but still the river was so pure that salmon were found going up. Now, on the Clyde, we have both chemicals and we have had an enormous increase of the water-closet system, but my impression is that the Clyde has become polluted in proportion to the increase in the quantity of excrement passing into it. Then, in considering the question of the disposal of sewage on a large scale, this question should be considered, that sewage is considerably lighter than salt water; so that if you pass it into the sea it will float, and very likely the decomposition will be retarded and rendered more slow by the addition of the salt in the salt water. Another question to be considered in connection with the disposal of sewage is the question of pumping. I think if you dispose of sewage at all by pumping, it is very apt to increase the risk to the public health. That, I think, is brought out by a return by Mr. Simon, in which there was an account given of the results of sanitary improvements in twenty-five towns in England. In a large proportion of these there was a great decrease in typhoid fever, but in the four lowest on the list there was either very little decrease at all, or an absolute increase, and in these four they pumped their sewage. As bearing upon that point, I may mention that Dr. Murchison, in the last edition of his work on fevers, when talking of the increase of enteric or typhoid fever in London, mentions it as a singular fact that that increase has been contemporaneous with the completion of the main drainage scheme of the Metropolis. With regard to sewage irrigation, I don't believe very much in it, but I believe it would be a positive evil whenever you required to pump your sewage; and I, perhaps, would go a little farther, and say that I think all the patents and all the plans that propose to deal with sewage at the outfall would have been of no sanitary benefit whatever, because all the mischief that arises to the public health is done before the sewage arrives at the outfall; and therefore, looking at it from a sanitary point of view—and it is from that point of view entirely that I am making my remarks—I think that no plan whatever which proposes to deal with sewage at the outfall would be a success in any way, or a benefit on any sanitary point whatever, especially if pumping was used, when it would likely be an evil, because the liquid would be pumped away, and the chances are that the gases would be left. I would here make a parenthetical remark on Messrs. Bateman & Bazalgette's scheme which I did not mean to make, but I will do it now with your permission. Messrs. Bateman & Bazalgette dwell with considerable complacency on what they call the impounding capacity of their sewers for storing storm water; that is to say, they do not propose their sewers to be made to carry off storm water at once, but they depend for the disposal of that storm water on the storing capacity of their sewers. I may illustrate that in this way: Suppose that after a long period of drought the sewers were about one-fourth filled with fluid, and a sudden storm comes on, and they fill completely,—the first effect of that is, to stir up the matter which has been lying there festering and fermenting, and the impure air impounded in this sewer is forced out by hydraulic pressure by the entering water, and must be forced either into houses or out some way into the city. Therefore I think in that respect, as well as in others, their scheme was not a correct one in a sanitary point of view.

229. They did not propose that the sewer was to contain the rain-water,—I mean, to impound it. They proposed, if I recollect rightly, what they called storm overflows; so that when the water rose to a certain height it would flow from these overflows into the Clyde?—They dwell on the storing capacity of these sewers for storm water.

230. But they did not propose, and I don't think it could be supposed, that the sewer which they projected would hold the total rainfall?—I thought it was singular; and that was why I mentioned the fact that they dwell with considerable complacency on the impounding capacity of their sewers. It is a good while since I read their report, but I think you will find that they speak in it in the way I have mentioned. I shall look over it again and mark the passage for you. Then the next question which naturally arises is, What is to be done? Of course I am looking at the matter purely in a medical capacity. Suppose there was an epidemic of cholera here or anywhere else, the Medical Officer of Health would at once try to get hold of the stools of the patients and disinfect them. But that would be a very difficult thing to do, and it would be very imperfectly done; and I consider that so enormous is the evil produced by the decomposition of human excrement, that the only true remedy is, that no decomposition whatever be allowed to take place, but that the excremental refuse of the population should be in one way or another—there are plenty of plans—either by chemicals, or by charcoal, or by earth, or by some other mode, prevented from decomposing. My impression is, that if attention had been directed earlier to that point, the problem would have been solved long ago, and that we would before this time have got quit, in part at least, of what is one of the disgraces of our civilisation, the deplorable amount of preventable death. I hold that no excremental matter whatever should ever be allowed to get into the sewers, but that the sewers should be kept to drain the surface and sub-soil water, and that the excrement should be dealt with in some other way. In that way you would have no gases, and would have no decomposition arising. You would also have this powerful check for the evil, that excremental stools of diseased patients would not get into the sewers to decompose and produce disease of the same kind. Of course, being here, I have talked about the sewers, but at the same time these excremental diseases are not produced solely from the sewers. A considerable number of them are produced by drinking polluted water; but if this principle were broadly laid down, that excremental matter should be removed within twenty-four hours after being voided, or subjected to chemical or other action rendering decomposition impossible, then you would at once check the spread of these excremental-pollution diseases. I think that, unless you have any questions to put to me, that is all I have to say.

231. What would you say to the excremental matter which is in the streets, for instance? I suppose you would not attach much importance to the excrement of horses, or other animals, which is dropped on the streets? It is the human excrement you refer to principally?—It is the human excrement, because I consider that water has a certain oxidizing power, and therefore, with the rainfall here, and the grinding down there is upon our streets, by the time the matter reached the river it would be practically innocuous.

232. Do you think the excremental matter of the streets might be allowed to pass into the sewers without danger?—I do.

233. I think the Pollution Commissioners make out that that excrement is almost as dangerous as the

other.—That is a point on which I should like to make some remarks. My answer to that is very simple. The Pollution Commissioners' reports refer to middensteads towns. There all kinds of refuse matter go into the middensteads, and by and by the ground gets saturated, and that saturated matter gets into the soil. That is, allowing the thing to decompose on the middenstead, and all the nuisance to escape into the soil, and from the soil into the stream.

234. But I am rather referring to what falls upon the streets. You think there would be no objection to that getting into the sewers?—It would do no harm, and the excrement of horses will not produce typhoid fever. Besides, the amount of that excrement would be very small in proportion to the quantity of water. Considering the large quantity of water which we have here, 50 gallons per head per day from Loch Katrine, and the enormous rainfall we have, I don't think there would be the slightest risk of pollution from the excremental droppings on the streets.

235. Can you give me any information as to the ventilation of the Glasgow sewers, or as to the extent to which they are ventilated?—To use the term ventilation, in the strictly scientific sense, they are not ventilated at all, because ventilation means the replacing of foul air by fresh.

236. But I mean are there any apertures along the course of the sewers?—There are plenty of apertures.

237. Because I have been looking about the streets, and I have very seldom seen any?—Still there are apertures. I may mention that it is now the rule that the soil-pipe in all new buildings should be carried right up to the roof and left open, but still that does not prevent the pipes from being decayed, as I have shown you. In good houses there are hot-water boilers, and the escape-pipe from them must be carried to the roof, generally in the soil-pipe. Often the rain-water pipe serves as the soil-pipe as well.

238. But are not these overflow pipes always trapped before they get to the sewer?—They are trapped, or they ought to be.

239. But still, what I want to know is, whether there are ventilators in the streets regularly and systematically? Are there apertures made from the street into the sewers in Glasgow? I ask the question, because I have looked about as I have gone along the streets, and I saw none. In other towns that I know they are frequent and regular, and made for the purpose of ventilating the sewers.—There are apertures here, but in many cases there are no openings in the apertures,—I mean, that they are closed with an impervious lid. In other cases there are slight openings, but they are so relatively small that very frequently they get choked up by the mud on the streets. I have seen that repeatedly; and I have also seen repeatedly—referring to what I said before about the destructive action of steam—steam come boiling out of these openings. In new sewers I think it is usual that there are apertures made; I don't think it is usual in old sewers. There is a return which Mr. M'Leod will present to you—which I moved for at the Police Board some time ago—that will give you all the information you want on these matters.

240. My observation merely goes to this,—You have stated, and I think very rightly, that mere water without air does not do much good in preventing the putrefaction of sewage; but of course if you don't let air into the sewers, there can be no air there, and I should say, from common observation, that that is not much attended to in Glasgow. I know that in other towns it is considered very important, and that great mischief has arisen in one or two cases from the neglect of it.—Still, when there are such openings, the vitiated air comes out and pollutes the air of the town.

241. Then you evidently attach great importance to the evils arising from pumping; but may not that arise in this way,—I don't suppose it will arise from the mere act of pumping, but does it not arise from this, that when you pump, it is from a place where the sewage stands until it is pumped out, and therefore where you have not a flow by gravitation? In such a case, is it not likely that the sewage will stand a longer time stagnant until it is removed?—Very likely that is so; and because provision is not sufficiently made for the escape of the gases. I may mention, as I see the thing has been mentioned to you before, that I had a closet fitted up on Hoey's limited system, to see how it would work. I was told it would not work; but it is now six years since I fitted it up, and it has been by far the cleanest closet in my house, and I have other five. Formerly it was a very awkward closet. When it was used I had to cover it with an iron cage with sea-weed charcoal; but since the limited supply has been introduced, it has kept perfectly clean. The water has always flushed the closet, and it has never cost me a sixpence for repairs. I merely fitted it up by way of trial and experiment. *Andrew Fergus.*

242. That shows the difficulty of getting at facts in these matters, for we had a gentleman here before who stated that these Hoey closets did not act at all?—It acts with me. I use it; my guests use it; and it is perfectly sweet. Of course mine does not go into a tank, as Hoey proposed; it goes right into the sewer; but one-fifth of a gallon has kept that closet perfectly sweet for six years; and it is in a room, which is a very awkward place for a closet.

Mr. James Brown, Housefactor, 8 Gardner Street, Glasgow, examined. *James Brown.*

243. I may say, Sir John, that I was for some years a clerk of works. I am a tradesman, although a housefactor now. I don't know that I can add almost anything to what I have stated in the pamphlet which I have put into your hands.

244. This paper describes what you suggest with regard to the drainage of Glasgow?—Yes; and there are estimates in it, and so on. I may say, however, that the scheme was introduced to the public first of all in 1858. I first talked over it, as I mention here, about 1854; and it was published in the *Bulletin* newspaper about that time. Some discussion took place upon it then, but the matter lay over. There have been different schemes of the same sort proposed since. The idea of the scheme is to intercept the sewage and drainage—to catch the sewage as far up the river as possible. My proposal is to catch it as far up as Tollcross, and Westburn, and Shettleston, and Carmyle, and to carry it down the Clyde on the banks.

245. Where to?—To the sandbanks below Dumbarton, below the Leven, and below Erskine House, away about Findlayston Perch. The ground there I take to be sufficiently large for the purpose. From low water-mark upwards it may run almost a mile in breadth, and there should be a stretch of somewhere about seven miles long from the mouth of the Leven to Ardmhor—that is, the sort of cape or promontory that there is before you come to Helensburgh. Several parties have taken up the same scheme; I don't say that they did so because they had no mind of their own, but the same idea has presented itself to a number of persons who have given their time and attention to the question. Some take one method and some take another of disposing of the sewage; some propose to carry it down both sides of the Clyde, north and south; and one gentleman, Mr. Paterson, I think, proposed to dispose of it by cutting off the river to some extent and forming large basins, and impounding it. Others, again, take the same mode of conveyance, and carry it down to Dalmuir, and so on. The only thing about the proposal which I make, to which I may draw your particular attention, is the number of tanks. I say there should be six; but I don't think that number would be necessary. Probably three would be enough. I take it that to hold a day's sewage, which I have mentioned at sixty million gallons on the north side, and forty million gallons on the south side, it would require on the north side a tank of about three-

James Brown.

quarters of a mile long, and half a mile broad, and about ten feet deep. I am not sure about the exact size, but I think it would not be far off that.

246. How many millions do you take the north side at?—Sixty millions, but that, of course, includes the ordinary rainfall. If the rainfall was kept out it would not require so much by a good deal. I may say, in explanation of my scheme, that I have all along proceeded on the assumption that the water-closet system is a fixed institution. We need not attempt to change it. There has been a great deal of talk about improving closets, and getting quit of the material that is in them; but it all comes to nothing, for you won't get the people to follow other people's ideas; and such talk, in my opinion, is a mere waste of time. Then a good deal has been said to-day about sewer gases. It was part of my original scheme to carry off the sewer gas. I proposed, and I propose still, that in running a main conduit along the Clyde for receiving the city sewers, and catching the sewage from these sewers, there should be openings or ventilators in that conduit along the river bank, sufficiently large to admit of a full draught of atmospheric air getting in; and my idea was to have openings, and to introduce pipes into the upper segments of the sewers at suitable distances, and to have these thoroughly fixed and hermetically fastened into the sewer. These would be led away into a main, and led out of the city into some upland locality, and passed into a stalk, or you might erect furnaces if you liked; but with these openings along the river wall, led away into that drain, the action of the air passing through the sewers would drive off the light gases formed in the sewers. I heard what Dr. Fergus said about decomposition accelerating its own action. If the decomposition is fairly met by the introduction of cold air, then it rather retards it; and the virulence of the sewer gases is very much destroyed by the introduction of atmospheric air. The lightness of these gases, however, necessitates their rise to the highest opening, and supposing that a vacuum is created by a furnace at that opening, then the cold air below drives the whole sewer gases clean away. With such a provision as that for removing the gases, the sewage could be led away into a conduit, and deposited upon some bank, such as I propose, down the Clyde. There is one thing with regard to the tanks which I may mention. I propose to fill up the tanks, after they are walled up, with the dredgings from the river, and, in the first instance, just to allow the sewage to fall upon them, and, as they are filled up, to introduce field drains plentifully into the space, and leave openings in the river walls, and the filtered sewage would run away into the river, on the same principle as proposed by Messrs. Bateman & Bazalgette. The only other remark I wish to make is about Messrs. Bateman & Bazalgette's scheme, and it has reference to a thing which has not been noticed, but which I think is an important thing. They propose to concentrate the higher level with the middle level about Ann Street and Duke Street near Tennant's brewery, and from there they propose to run it down Hunter Street and along a continuation of that street down to Great Hamilton Street and across the Green. There is no Hunter Street now, because the railway people have taken it away; but then they propose to carry a large sewer across the Clyde, just above the weir which is at present in existence, and carry it on arches up Rose Street or in the immediate neighbourhood of it, and then along by Cumberland Street, and on to Pollokshields; and they propose to have large pumping appliances nearly opposite to the jail. At that point the two burns, the Molendinar burn and the Camlachie burn, unite, and they would have a pumping station there. If they formed a deep enough pit, the whole thing would be thrown up, and then it would be driven away into this tube or tunnel that is carried across the Clyde, and then carried down to Pollokshields, where there would be another lift. Now, all that pumping would, in my opinion, be most injurious, and it would create a noise in the city that would not be tolerated.

247. How would you propose to get rid of the necessity for pumping?—The sewage could be run down so far by the Clyde; and then if any pumping was required, it could be done at a point farther down.

248. You propose to go down to some distant point, and introduce the pumping there?—Yes. It could be done out of sight in some spot that was sheltered by foliage, and that would prevent any offensive smells. I have here a plan,—I am not at liberty to leave it, but it is one of those schemes which followed mine, and it shows a method of carrying it off as I proposed. Dr. Gray showed this plan and read a paper to the Philosophical Society some time ago, and Mr. Baldie furnished the chart. He carries the sewage on the south side down to Newshot Isle, and on the north side to Dalmuir. There is a good deal of waste ground about there, and I am not sure that in some respects it is not better than my proposal; but I am not perfectly acquainted with it. My plan carries it down to Dumbarton, to the bank which I propose there.

249. You would carry it below Dumbarton?—Yes, and thus catch the sewage of Dumbarton as well. My plan would catch the sewage of all the places round about—Maryhill, Duntocher, Kilpatrick, and up the Clyde as far as Carmyle. Then, on the south side, you have Rutherglen, Pollokshaws, Pollokshields, Renfrew, and other places. The whole thing is taken up. Any scheme that does not thoroughly take in the whole sewage passing into the Clyde, at least from Carmyle downwards, would fail in its object, and it would only require to be gone back upon some years hence for something better to remedy the defects of the plan. At one meeting at which I was present, Mr. Deas, the engineer of the Clyde Navigation, was saying that, in order to carry out such a scheme as mine, we would require to make the water run up-hill; but I don't see that we need to do that, for Mr. Baldie's sections show that there is a good enough run down to the Clyde. I may say that the first thing which suggested this scheme to me was a chart of the Clyde furnished to the Town Council by Mr. Kyle, surveyor, Glasgow, at the time when the Council were applying for an Act of Parliament for the formation of Kingston Dock, I think about 1838. It was from the levels which I saw upon that plan that I fell upon this scheme of carrying the sewage down as I now propose. I think Mr. Kyle is quite correct in his levels, and that there is a very good fall indeed, if it was properly worked. Of course, if the thing is blundered, it is of no use; but I think the sewage can be carried down with a sufficient fall to give at least the maximum flow mentioned by Messrs. Bateman & Bazalgette.

Mr. Thomas Reid, Farmer, Monckton Mill, Ayrshire, examined.

250. I have nothing new to suggest on this matter, but I am very much interested in it as a tenant farmer, and I wish to support Messrs. Bateman & Bazalgette's view as to the disposal of the sewage. I have had the same opinion for upwards of thirty years, and I have levelled nearly one hundred acres of sand-hills on the Ayrshire coast in the prospect of some such scheme being carried out. I have got sick of the matter, because it has been delayed so long without anything being done; but I hope that something to the purpose will be done now. Messrs. Bateman & Bazalgette called at my place when they were here, and made a survey before they gave in their report; and I hope you will also come and see it, if you require to come down to the coast on this occasion.

251. I have been there twice already. Where is your farm?—It is three miles on this side of Ayr. The railway passes through my farm, and the station is in the centre of it. The land which I have levelled was with the prospect of getting the sewage on to it some day; and I look forward to getting it yet. I will be able to pay the Glasgow Corporation as much rent for it as I pay to my landlord, because I consider that by

irrigating it with sewage, they will raise the value of the land as much as if they became proprietors of it.

252. Are you not your own landlord?—No, I pay a rent. My landlord is Captain Campbell, of Irvine.

253. How near is the Duke of Portland's property to your farm?—It just adjoins my farm. There is a small burn that comes from three or four parishes, and that goes into the sea there; and that is the only proper outlet between here and Irvine where the sewage could be brought down and be carried away with any supply of water in addition to what came from Glasgow. Another thing is, that there is not a house within more than half a mile of the place; the proprietor's house is about a mile away. My view of the whole matter is, that we farmers, with regard to our fields, are just the same as the tenants of houses in towns. They get gas and water into their houses and pay for them, and we want sewage into our fields and we are willing to pay for it. Whenever water and gas are introduced into a house, the rent of that house is raised; and in the same way, when we get sewage into our fields the rent rises, and we are willing to pay the increased rent. I would pay as much for a supply of sewage as I would do for artificial manure; and I pay almost as much for artificial manure at present as I do for my rent.

Mr. Alexander Gray Simpson, of Carfin Hall, examined.

254. My idea is to have a large tunnel or sewer on each side of the Clyde; to collect the whole sewage into that tunnel or sewer; to have seven depositing ponds, one for each twenty-four hours; to collect, by means of the tramway rails, all the sweepings, contents of ashpits, and everything during the night; to run them in on the top of these ponds, and let them out with a hopper on to the top; to drain all the water into the river with the fall of the tide, one of these ponds to be emptied every twenty-four hours; if necessary to get quit of the gas, to have funnels at intervals throughout the course of each tunnel, and if it is necessary to increase the ventilation of these funnels, to do so by means of vents or otherwise, as may be found expedient. I think that is all I have to say. In that way, what is put into each pond would have about a week to consolidate, when it could be removed by the railways throughout the country.

255. Have you formed any opinion as to the distance you would go down the Clyde?—No; but I would go down to the most convenient place, and I should say that it would be pretty well out. If it was necessary to flush the tunnels, that could be done from the Clyde, from Rutherglen Bridge. The water could be taken off there to flush the tunnel right through, if the sewage was not liquid enough to serve the purpose.

256. Is that after the weir is away?—No, it would be taken off above the weir.

257. I understand you are a large coal owner?—Yes.

258. Do any of your pits drain into the Clyde?—Yes.

259. Where are your pits?—They are above Motherwell.

260. I suppose the water you raise from the coal, generally speaking, is not very deleterious?—No.

261. I saw one place where there was a good deal of iron, but, generally speaking, the water that came from the pits that I saw was very clear?—Yes, in this district. In iron districts it sometimes destroys fish.

262. What is the depth of your pits generally?—From 70 to 90 fathoms.

263. Is that the general depth in the neighbourhood?—There are a good many seams there, and they range from 20 fathoms (that is, 40 yards) up to 120 fathoms.

264. You are in the Wishaw district?—Yes.

265. To what depth are you troubled with water?—The greater part of the water is at a depth of about 50 fathoms from the surface. The heaviest part of the water is there.

266. Are any of your deep pits quite dry?—Yes; they are dry in the bottom.

267. I suppose at a depth of 120 fathoms they would be dry?—Oh, yes; comparatively dry.

268. I know that in South Wales you get into a depth where you are perfectly dry, but the pits there are deeper than you have mentioned.—Yes, much.

269. How many beds of coal do you get in the Wishaw district? I put the question because I want to get at the amount of settlement there would be on the surface?—I should say that there are six seams at an ordinary depth; what we call the upper seams.

270. What thickness of coal would that represent on an aggregate of all the seams?—About 25 feet.

271. What effect does that have on the surface, suppose you work out all these six seams? How much would you expect the surface to go down in that case?—That depends very much upon the nature of the cover. If the superincumbent strata is of a light, friable nature, then, as you go down with your sinking, it gradually falls of itself; but if it is close and regular, then it falls at once. Each district varies very much in that way. Then, again, it is seldom that the whole of the seams are removed. The thinner seams are all taken out, but in the thicker ones there are pillars left to support the roofs, and these pillars are not generally got out entirely, so that in that case you have not a complete subsidence. I may say that the greatest subsidence of surface that I recollect, at the moment, of having seen, is about 15 feet. That was where three or four seams had been worked out, and in that case some of the seams were very near the surface.

272. Is that a common occurrence?—No; it is not a common occurrence.

273. Do you get coals under the railways in your district?—Yes. There are some of the old Acts, however, under which the coal has been taken with the land.

274. Did the railway companies buy it?—They did not buy it, and that is a question upon which there is a little doubt. In the early days of railways in Lanarkshire, the proprietors were of course very anxious to see them there, and in some cases they gave the land free. The railway companies hold, that in giving the land free they also gave the coal.

275. You have just given me 15 feet of subsidence, and you say that that is rather an unusual case. What would you call a general subsidence?—I should think from 4 to 5 feet.

276. Do you know much about the coal betwixt Glasgow and Hamilton, for instance?—Yes; I have a general idea of it.

277. What amount of subsidence would you expect to have there? as much as 4 or 5 feet?—I rather think not. The coals are at a much greater distance from the surface up there. The first coal that is got in the Bothwell and Hamilton district is, I should say, at a depth of about 120 fathoms.

278. Is that the top bed?—Yes.

279. Would you apply that to the whole district betwixt Glasgow and Hamilton?—Up towards Rutherglen, nearer Glasgow, it is not so deep. You would have to take it in two sections there. I think you could not get an average of the two very well.

280. What would be the average between Glasgow and Rutherglen, for instance? What is the depth of the top bed there?—I am rather afraid to give any figures about that, because I would not like to say anything that would not bear close inspection. I know more about the district farther up.

281. But you say that the top bed there is rather nearer the surface than farther on?—It is.

282. Then, between Rutherglen and Hamilton, what is about the depth of the top bed?—About 120 fathoms. There is a district called Cambuslang, near Rutherglen, where the depth is not so much, but after that the cover increases considerably.

283. The bottom bed there would be at a great depth?—Yes.

Alexander Gray Simpson.

284. What would you expect to be the subsidence of the surface in that district where the top bed was at a depth of 120 fathoms?—It would be very little, because all above the soft coal is mostly what we call soft metals, and it would fill itself up gradually.

285. What is the thickness of your thickest beds in that district?—8 feet. Of course it varies, but I am giving you about the average.

286. Are the others much thinner?—Yes; they are from 3 to 5 feet.

287. In these thicker beds do you always have to leave pillars?—Yes; and in addition to the pillars we have to leave a part of the coal. The roof does not stand of itself. There is what is called head coal usually left on. A good part of it is taken out when coming home, as we call it, after we have got the bulk of the coal out.

288. But you don't work out the whole of the coal?—No.

289. It does not pay, I suppose?—The quality is inferior. By working this head coal along with the principal part of the coal you would injure the quality of the whole.

290. Do you know anything of the coal below Glasgow, or of the iron mines which I saw working in the direction of Paisley?—No; they are of more recent date, and I have not been down them. I have a general idea of the thing, but I cannot give you any reliable information about them.

291. How are the pits above Airdrie? Do these resemble yours at all?—Very much. They resemble the pits in the Wishaw district more than those in the Bothwell or Hamilton district, but in the Airdrie district they have not got this Wishaw coal, what is technically called the Ell coal. They have got it, but not in the state in which it is at Wishaw. It is very thin at Airdrie, and is not worked at all in most instances.

292. What is the floor of your coal pits here generally?—There is usually a little fire-clay.

293. Is that what we call white earth?—Yes.

294. Is the roof harder?—Yes.

295. Do you use much timber for propping?—Yes.

296. What do you generally use?—Foreign timber.

J. C. Wakefield.

Mr. J. C. Wakefield, of Messrs. Inglis & Wakefield, Busby, examined.

297. I am not here to propound any scheme, but from the benefit, in my opinion, that will arise from the use of dry-closets, I thought it right that my experience should be known. We have had the dry-closets in use for a number of years, and have found them to work very well. My opinion with regard to the sewage is, that it is the soil from water-closets that does the great damage to the water in the Clyde, more than almost anything else. We employ about 800 people, and we have adopted these dry-closets for a number of years, and have found no difficulty whatever with them.

298. I remember seeing them when I was there. You use earth-closets?—Yes, but we use ashes instead of earth. We formerly used earth, but we found the ashes to do as well. I consider that in large blocks of buildings, or in large factories in the vicinity of any river, these dry-closets could be made to pay, independent of saving the great loss which is caused by sending such matter down the rivers. We get 4s. 6d. per ton for all the ashes and soil together, and we remove it daily. If a large reservoir were made to hold it, it would not require to be removed daily, and therefore the profit then would be much larger.

299. You get that 4s. 6d. per ton at your works?—Yes; the farmers take the stuff away, and I believe we could sell far more of it than we make.

300. Then you would not think it was any hardship to put all public works under the necessity of purifying their sewage before it is discharged?—None whatever. I think it would be a great benefit to the manufacturers themselves, and it would also be a great benefit to the farmers in the neighbourhood, because I consider that that sewage is a very valuable property. We have no difficulty at all in utilizing it. We employ a man who removes it daily; and if in large blocks of buildings you could collect a week's supply, you could then remove it at very little expense in comparison with the expense that we are at in removing it every day.

301. Are you at all acquainted with the plan which Mr. Thom has applied at his print works at Chorley?—No. I have never been there.

302. I went there to see it purposely. I do not know that I can explain it very well, but it consists in collecting all the coloured matter or soapy matter, which he carries off into a place not much bigger than this room, and there he uses two chemicals—the muriate of soda, I think, is one of them—which precipitate the colouring matter and the soapy matter into tanks. He has two or three of these tanks, and when the colouring matter and oily matter is collected, it looks very much like red soft-soap. He then passes it into casks, and he told me he was selling it at £5 per ton. I asked him if the thing was any expense to him, and he said, No, that he rather considered it a profit, and it did not require much room. Of course there is another liquid from his works which he cannot deal with in that way—the washing water.—We have a large reservoir for that.

303. He has two or three reservoirs, and he simply passes it from one to another and lets it settle.—That matter or refuse must go into these large reservoirs, because it is of no good for the land.

304. But the colouring matter and the soapy matter can be used?—There are certain things no doubt that can be precipitated and be valuable, but we have not adopted that system.

305. It seemed to me to be very simple, and it did not take up much room, which is a very important thing for some works that have not much space. Mr. Thom wrote an account of his system for the Society of Arts in London, and the water certainly passes into the river perfectly clear.—My own impression strongly is, that the dry-closets are not sufficiently known to be properly appreciated. We find them to be very useful, and in fact before we adopted them we were continually annoyed by the smells about the works, and the filth that constantly accumulated. We could not get the people to be so decent as they are with the dry-closets; and I came here merely to give my own experience with regard to them, believing that the thing is not in sufficient practice or so well known as it ought to be. Certainly, in all large print works, and large manufactories of every description, it would save an amazing deal of refuse from going down the rivers, and ashes could easily be procured in all these places. There might be a little difficulty in towns in getting a sufficient supply of ashes, but we are only too glad to get rid of a hundred tons of ashes at any time, for we are troubled with them if we cannot get them away. We are obliged sometimes to bury them.

Mr. Thomas Short, 4 Kelvingrove Street, Glasgow, examined.

306. The witness produced a model of an apparatus for purifying sewage, which he explained, and with reference to which he handed in the following paper:—

'*Intercepting and Purification of Sewage and Sewage Gas, and Utilizing the Sewage.*

'This invention has for its object the intercepting and purifying of sewage, by removing from it the various suspended matters and impurities, so that the water may subsequently flow into a river, canal, or harbour without polluting the water therein.

'This apparatus is designed for being applied in the course of any main sewer, a certain length of such sewer being removed for the reception of the apparatus, which it is proposed to construct principally of cast-iron.

'The apparatus comprises two chambers or compartments, peculiarly contrived and fitted, with the view of promoting the deposition of suspended matters, and the sewage water is allowed to flow through one of these chambers when the deposits are being removed from the other.

'The water and gases, before finally leaving the apparatus, are made to pass through quantities of suitable charcoal, contained in cages, arranged so that they can be easily removed for emptying and re-filling.

'The flow of the sewage water is temporarily retarded by the action of a water-wheel, which it is made to drive on entering; but the force imparted to the water-wheel is utilized in working the pumps and fan, and in restoring a large proportion of velocity to the purified water as it leaves the apparatus.

'And in order that I may be properly understood, I have made out large drawings and a model, representing a modification of this machine suitable for a main sewer.

'In these drawings the same reference numerals are used to mark the same or like parts wherever they are repeated.

'Figure 1 is a side view, figure 2 is a plan; whilst figures 3, 4, and 5 are transverse vertical outlines. The apparatus is formed with a flanged inlet (1), at what is represented as the left-hand end, for connection to the main sewer in the course of which it is placed; and just within this inlet there is formed a chamber or enlargement (2), having fitted within it a paddle-wheel (3), which the sewage water turns on entering, losing a little of its velocity in doing so. After passing the wheel, the water proceeds by a deepening passage (4) to the entrances to two passages (5, 6), commanded by sluices (7), only one of which is open at a time. Most of the chambers and spaces are in duplicate, and separated from each other by a longitudinal vertical partition (8), extending almost the entire length of the apparatus, and it will only be necessary to describe one set, and the parts appertaining thereunto.

'By the passage (5)—best seen in figure 2—the water enters a depositing chamber (9), the bottom (10) of which is formed with large openings, leading into what may be termed a mud chamber (11) below.

'In the chamber (9) there are a number of baffling plates (12) and gratings (13), which tend to break or arrest the currents, and thereby favour deposition. The gratings (13) are in the interior or front part of the chamber (9), and are inclined and arranged so that the water has to move upwards, or partly upwards, in passing through them. The space (14) forward of the gratings (13) communicates with a front mud chamber (15), and there is constructed, so as to dip into the intermediate space, a chamber (16) formed by a back perforated partition (17), which is nearly vertical, and by a forward perforated partition (18), which is formed with horizontal baffling plates (19), and is inclined to favour deposition. Within the chamber (16) there is a cylindrical well or compartment (20), into which the water flows through very small perforations, excluding all but the finest suspended particles. In the well (20) there is a pump (21), which is by preference of the kind known as the Archimedian or helical pump, which may be placed vertically as shown, or at an inclination. The mud chambers (11, 15) are formed with inclined bottoms (22, 23) at the middle of the apparatus, to favour the lodging of the mud towards the ends, from which parts it is to be periodically removed by means of pumps arranged to exhaust it through pipes (24, 25). The central pumps (21) are worked by gearing (26) receiving motion through a longitudinal horizontal shaft (27), indicated by a line from the water-wheel (3). The water flowing up and raised by the pump (21) passes on over the top of the forward part of the chamber (16) towards the continuation of the sewer; it has, however, on its way to the sewer to pass through charcoal, as hereinbefore mentioned. The charcoal is contained in rectangular iron boxes or cages, formed with close sides and bottoms, whilst the front and back ends are made with the upper halves of perforated metal plates, having half-inch holes about an inch from centre to centre, through which the sewage gas is purified, and with the lower halves three-eight inch vertical rods, with three-quarter inch spaces. The cages are fitted with anti-friction rollers at the corners to bear on vertical guide bars in spaces (28, 29) formed for them near the forward end of the apparatus; and in the course of the outflowing waters close-fitting doors are provided in the top of the apparatus over the spaces 28 and 29, to admit of the introduction and removal of the charcoal cages.

'Finally, in the outlet (30) leading to the continuation of the sewer, there is a screw propeller (31) driven by a continuation of the shaft (27), which, as hereinbefore stated, derives its motion from the water-wheel (3) at the entrance, and this propeller restores to the outflowing water some of the velocity which it had at the inlet. The propeller (31), by sucking the gases and air from the course of the sewer, facilitates the flow of the sewage, and therefore is not so liable to settle and decompose before being removed.

'The water-wheel, which is on the principle of Poncelet's undershot water-wheel, is balanced by two levers and weights, so that should anything come down the sewer and stop the wheels the buckets will get filled, and the wheel being balanced it is forced up and relieved, and then goes on as before.

'All running gear will be on anti-friction rollers, so that the tear and wear will be comparatively little, and can be run with much less power than if made in the ordinary way.

'I estimate the excremental and other refuse at 200 tons per day, thrown into the river by the sewers and wasted; take this as worth nothing more than the cartage (2s.), and if made into charcoal at a cost of 6s. per ton gives £21,900

'Suppose, now, 73,000 tons of sludge gives 26,000 tons of charcoal at the very moderate price of 20s. per ton, . . 26,000

'Leaving a balance of . . . £4,100'

307. How much sewage do you estimate you would have to deal with by this process?—Seventy gallons per head per day for the whole population.

308. That includes the rainfall also?—Yes.

309. How much do you estimate your process would cost for the whole sewage of the town?—From £125,000 to £130,000.

310. Does that mean for the cost of the machines?—The cost of the machines complete, and the working apparatus. That is for putting the whole thing into working order.

311. It includes the excavation of the pit for receiving the machines and the cost of the machines themselves?—Yes.

312. But it does not include the manipulation afterwards?—No.

313. What do you estimate would be the cost of providing the filters, putting in the charcoal, and taking it out and taking away the material; or have you gone into that at all?—I expect that by a machine that I am working at just now I will be able to manufacture charcoal that will serve the purpose; and supposing it had to be lifted every day, it would cost about 4s. 6d. to 4s. 9d. per ton.

314. I have already got from you that you estimate that £130,000 would provide machines for the sewage of the whole city; but I want to get at what would be the expense to the town of working these machines. I mean what would be the cost of taking out the solid matter, and lifting the charcoal filters and renewing them, and so on; have you formed any estimate of what that would cost?—Not more than 10d. per ton for the refuse thrown into them.

315. And how much would you take the refuse thrown into them to be?—About 200 tons a day.

Thomas Short.

Probably it would be above that, but I have given that as a minimum figure.

316. Are you a mechanic?—Not practical.

317. That is not your business?—No, although I have been about twenty-five or twenty-six years connected with it.

318. Do you mean connected with sewage?—No; connected with engineering.

319. Are you a civil engineer?—No. I am a mechanical engineer, but not practical.

320. But you have been connected with engineering establishments?—Yes.

321. Have you tried this machine and its effect upon sewage?—Yes; upon made-up sewage, but not sewage proper.

322. How was it made up?—It was just sweepings, and so forth.

323. You made some artificial sewage, and then you tried it on the machine?—Yes.

324. What was the result? Did the water come out clear?—It came out perfectly clear.

325. But I suppose you have no chemical analysis of the discharged water?—No.

Kenneth M'Leod.

Mr. Kenneth M. M'Leod, Sanitary Inspector for Glasgow, examined.

326. I now hand in an official copy of the reports received by the local authority with regard to the purification of the Clyde.

327. Do you wish to say anything with regard to these reports?—Not unless you wish to make any inquiry regarding them. I merely wish to state that the latter part of the volume was got up upon a motion by Dr. Fergus, who has been examined to-day; and the first report by myself was prepared after a memorial had been received from some ratepayers complaining of the pollution of the Clyde, and it gives a full account of the sources from which the pollution comes.

328. Can you tell me in what manner the sewers of Glasgow are ventilated just now?—They are ventilated by street gratings. There are very few of the street gratings trapped. They are mostly all open gratings, and the man-holes are almost all ventilated too.

329. You have not been in the habit of having ventilators placed directly over the sewers, as we have in England?—We have a good many in the centre of the streets. Every man-hole of the main sewer is a ventilator—that is to say, it is an open grating.

330. But have you, besides these, some ventilators directly over the sewers?—None. About two years ago I made a survey of the city, and asked the manufacturers to allow us to ventilate through their chimneys. I got the consent of upwards of 100 of them; but the local authority found it was to be a very expensive matter, and they only ventilated one.

331. Can you give me any idea as to how frequently you have ventilators? I mean what is the average distance between them?—They vary very much. I cannot give you that information.

332. You do not have them at stated distances, I suppose?—No. Mr. Carrick, however, would be better able to give you information on that matter. All the drains are under his charge.

333. Is there any further explanation you would like to give upon these reports?—I think not.

334. Have you charge of the men who are employed about the sewers, or is it Mr. Carrick?—Mr. Carrick.

335. Have you many of what are called ashpits in Glasgow?—A great many. The number of them is given in the reports which I have given in.

336. Are they generally covered or open?—There are very few of them open now. They used to be all open, but we are getting them covered up every day. There is an abstract of the whole of these things at the end of the book which I have put in.

337. Have you formed any opinion as to what should be done in Glasgow about the sewage?—I have not formed an opinion sufficiently to give it public expression yet.

338. You perhaps know something about the Hoey water-closet?—Yes; I have seen it. It has too little water. I think that is one fault of it.

339. What is the actual quantity of water allowed?—About two gills, I think; or half a pint.

340. Do you mean that there is not more than half a pint allowed for each sitting?—That is what was aimed at.

341. So far as your observation goes, do these closets seem to keep themselves clean and clear?—The persons using them complain a good deal about that, and that is the chief complaint, that there is too little water. There are two or three of these closets not far from here, and they can be seen quite easily.

342. Who puts them in? Is it any plumber?—There are very few of them in the city. It was Mr. Hoey himself who put them in, but they have not been adopted to any extent in the city. I find that the carbon-closet—that is, the dry-closet—works wonderfully well in some places here.

343. That is using charcoal instead of earth?—Yes; they work very well wherever they are properly attended to, and I think they give the greatest satisfaction.

344. Are they expensive?—No; I think £2, 10s. would furnish a very nice one.

345. How much charcoal would be used in a day?—Not a very large quantity at every use. I can get the exact quantity, if you wish it.

346. I have seen complaints about them being rather dusty or nasty?—We do not find them so. A good many warehouses here have adopted them recently, and they are highly pleased with them. They are putting away their water-closets, and taking these dry-closets in preference.

347. Who cleans them out? Is it the parties themselves?—There is a company that furnishes the charcoal, and in exchange for it they get the excreta and charcoal together again. They remove it periodically.

348. There is a company here who do that, so that the parties have really no expense connected with the closets?—No expense whatever. The company are quite ready to furnish the charcoal in exchange for the excreta, but persons adopting them must get the consent of the local authority, because the local authority have all the manure of the city, and it is necessary to apply to the local authority when they put in a closet of that kind.

349. Who are the makers of the carbon-closet?—The Carbon Fertilizing Company, in West Regent Street, Glasgow. The head office is in London; General Singh is at the head of it there.

Mr. John Carrick, Master of Works (recalled), examined.

350. With reference to a note which I have received from Mr. Nicolson, I may state that we have never provided in Glasgow what I may call a formal mode of ventilating sewers. I myself formed an opinion many years ago that to trap all the street gratings, without providing an efficient means of ventilation, was very doubtful policy, and except in one or two cases, where we had a discharge of steam, owing to the hot water from some of the public works that are in the centre of the town, I have allowed all those street gratings to remain open as the only ventilators to the street. In London, of course, the man-hole, with the ventilator in the centre, answers the same purpose, but here we have, in my opinion, very general ventilation in the sewers, arising from our rain-water conductors, which almost all communicate with the sewers. We have had one or two cases where the covering in of a large water-course has led to inconvenience, and then we have applied a ventilating shaft, which has had the effect of relieving the pressure; but we have no means,

in ordinary cases, except the rain-water conductor and the ordinary street grating, of ventilating the sewers. I may say that we have had no complaint of sewer gas in Glasgow, except along the valley of the Pinkston Burn, in the Cowcaddens district, where we receive the drainage of various chemical works and distilleries. There the action of the chemical refuse, with the discharges from the distilleries, sets free the sulphuretted hydrogen, and we have had great complaints from that part of the town for many years. We have had to meet the evil by trapping the main sewers themselves in some cases, so as to prevent the escape of the gas from the main sewer up to the higher levels, which we found it had a tendency to reach. In some cases there have been great complaints, owing to the gas getting into the dwellings of the parties living in that district, and we have attempted some mode of ventilation there, by means of street lamps, but only to a very limited extent. My own feeling is, that in order to make things right, there should be a means of ventilation provided for sewers in all circumstances.

351. You say that the rain-water pipes afford a means of ventilation, but in heavy rains (and you have a great deal of rain in Glasgow) these rain-water pipes, instead of letting the air get out from the sewers, would be rather forcing it into them?—Of course, but then, on the other hand, our sewers in Glasgow are at such short distances that we have had really no complaints of sewer gas, except in those cases I have mentioned, where the sewers receive the deleterious matters which are discharged from the chemical works and distilleries.

352. Have you had no complaint about gases escaping into houses?—Not from the main sewers. I should say that any defect of that kind arises from imperfections in the private drains; and we make a point of the soil-pipe being always carried up through the house to the roof, so as to prevent the pressure of sewer gas upon the water-traps.

353. How do your rain-water pipes communicate with the sewers?—There is one which can be seen from the window of this room, on the building opposite. I think myself that the ventilation of the sewers would be best effected by having the drains from houses and the soil-pipes of every house so free as to give a means of ventilation.

354. In London they used to have the ventilators right over the centre of the sewer, but latterly they have put them a little to the one side, so as to prevent choking; because when they were in the centre of the sewer, gravel and other things used to drop through the grating, and gather into a heap in the bottom of the sewer, and obstruct the flow.—Still, in point of fact, if the gully grating were not trapped you would require no other ventilation for the sewer.

355. That would depend on how numerous they were, and at what distances they were placed. How near are your gully gratings?—They are very close, and they must be so in large towns. Where you have streets, as in Glasgow, at an interval of never more than 100 yards, you are compelled to have a gully grating there; and besides, at mews lanes and at places of business, you may also require to have gully gratings, so that you may have them every 20 or 30 yards.

356. If they are clear, they ought to act, but the shorter the distance they travel the better.—In the case of the Pinkston Valley, where we found the nuisance arising from that chemical drainage which I referred to, I was afraid of trapping the drains, because it increased the evil in the houses. In some cases we applied Stanford's charcoal filter in one or two parts of the town, where there were complaints as to the steam rising, and we found it to act beneficially.

357. Have you any pit at your gully to receive the detritus?—No; it is all just as it comes into the sewer. I may say that we have no deposit in our sewers, or at any rate it is very trifling.

358. Have you much macadamized road in Glasgow, or are your streets generally paved?—They are generally paved. We have perhaps about 18 miles of macadamized road leading to the outskirts of the city; but the streets in the centre of the town, amounting to nine-tenths of the whole, are paved streets. *John Carrick.*

359. I suppose you have generally good gradients in your sewers?—Yes; very good.

360. You have not many flat sewers?—No; we look on anything above 1 in 120 as being bad.

Mr. William Campbell, Assessor under the Lands Valuation Act for the Burgh of Glasgow, examined. *William Campbell.*

361. I produce a statement giving details as to the number of houses, population, and annual value in the burgh of Glasgow:—

Number of houses in the burgh for 1874,		111,357
On north side of river,	86,486	
„ south „	24,871	
Estimated population of burgh for 1874,		534,530
On north side of river,	415,420	
„ south „	119,110	
Rental or annual value for 1874,		£2,740,032 19 0
On north side of river, £2,295,477, 2s.		
„ south „	444,555, 17s.	

I also produce a statement applicable to certain of the suburban districts:—

Govan—No. of houses in 1874,	7,429
Estimated population,	37,120
Rental,	£143,229
Partick—No. of houses in 1874,	4,754
Estimated population,	23,770
Rental,	£95,981
Maryhill—No. of houses in 1874,	1,517
Estimated population,	7,585
Rental,	£30,939
Crosshill—No. of houses in 1874,	564
Estimated population,	2,820
Rental,	£19,619
Crosshill District (embracing Pollokshields, Strathbungo, and Mount Florida)—No. of houses in 1874,	2,556
Estimated population,	12,780
Rental,	£78,068
Kinning Park—No. of houses in 1873,	2,042
Estimated population,	10,210
Rental,	£30,855
Hillhead—No. of houses in 1874,	822
Estimated population,	4,110
Rental,	£48,746

I have also been asked by Mr. Nicolson to make up a statement, showing the number of tenements in Glasgow; that will take some little time, but I shall prepare it, and put it in afterwards. I may explain that the burgh of Glasgow was extended in 1872. There is a considerable area now within the municipal burgh that was not within the Parliamentary burgh—somewhere about 970 acres—embracing what is called the ancient royalty or Springburn district to the north, a little portion to the south, the Alexandra Park, and the present University at Gilmorehill.

362. Then the extended burgh is not now called the Parliamentary burgh?—The municipal burgh and the Parliamentary burgh were co-extensive until 1872; but the area of the municipal burgh is now much larger than that of the Parliamentary burgh.

363. Is what you have given us as the burgh all included within the municipal burgh?—Yes.

William Campbell.

364. Are these what you called the suburban districts included within the municipal burgh?—No. They are all beyond the municipal burgh. They are the districts surrounding it on the south, west, and north.

365. Suppose the Act which the Corporation are applying for this year were passed, would it include the whole of these outlying districts?—Not the whole of them. It would include Crosshill and the district lying between Crosshill and Glasgow; but although not in the burgh, I was desired to give the information with regard to these outlying districts, and I have done so.

THURSDAY, 20*th May* 1875.

William Strang.

Mr. William Strang, Manufacturer, 64 Gordon Street, Glasgow (recalled), examined.

366. I should like to make a remark with regard to a report by Dr. Wallace, which I see, from the newspapers, has been handed in to you. I may be allowed to state that the machine which I described when I was here before was the third machine that I had exhibited to the Town Council. The first one was put up privately in a house in Crown Street, where I showed it to some of the members, and they asked me to fit up one in the 'Old Man's Institution.' That was the one which Dr. Anderson reported on, and whose report you have got. Some time after that the Town Council went into it again, and they agreed to spend £500 or £600 on trying three schemes—Hoey's, Chapman's, and my own. I got a place from the Town Council, in which to fit up my machine. I had nothing to do myself with selecting the place, but they gave it to me, and I fitted the machine up there. I fitted up two machines in the block of houses which they gave to me, and I was waiting on, expecting that they would let me know when the machines were to be tested, or who the chemist was that was to be employed, so that I might have an opportunity of seeing that the machines were properly looked after before the test took place. I expected to know at least when they were to take off the samples, so that I might see that the machines were in proper order at the time, because if they were not emptied regularly, or attended to regularly, it could not be expected that they would work properly. The keeping of the machines in order was looked after by the city, and not by me. I had no control over it. The matter was taken charge of entirely by the city authorities, and if the machine was not kept in proper order, of course it was impossible for it to have a fair test. I now wish to draw your attention to the second sentence in Dr. Wallace's report, and I think it will bring out clearly what I wish you to notice. He says in the opening sentence of his report: 'Gentlemen, in accordance with your request I have made careful analyses of the products resulting from the various systems of disposing of the sewage which have been for some time under your consideration, and now beg to report.' The next sentence is the part of his report which I feel very much: 'The various samples were collected by Mr. Ellison'—who was superintendent of cleansing in Glasgow at that time, but who has since absconded—'with the exception of those resulting from Chapman's and Hoey's processes, which were supplied by Mr. Gavin Chapman.' You will observe from that that Mr. Ellison and his men collected the samples from the machines which I had fitted up; but Mr. Chapman, who was one of the competitors, knew the chemist, and was allowed to take his own samples, although I never even knew that the samples were being taken off the machine.

367. What you complain of is, that in the one case the samples from your machine were taken without your knowledge, and in the other case the parties themselves furnished the samples?—Yes, that is one of the things of which I complain. I did not even know that the samples from my machine were taken off. Of course if the machine had been worked by me, it would have been quite right for them to have taken off the samples at any time they liked, so that I might not have been able to doctor the machine; but when they had charge of it, it was surely right that they should have let me know when the samples were to be taken, in order that I might see that the machine was in proper order. If the stuff is not taken away from below, the machine gets perfectly saturated with urine and soil; and in that case it is utterly impossible for the water to come off pure. Dr. Wallace's report was the first notice that I got that the thing had been done. I have here a copy of Dr. Anderson's second report, with which I promised to furnish you. It is a true copy. I have a printed paper here which gives Professor Anderson's analyses in a condensed form, and I now hand it in for your consideration. These analyses have reference both to the effluent water and to the water which comes out from below. The large drawings of my machine are not yet ready, but I shall send them in when they are done.

Mr. Edward C. C. Stanford, F.C.S., Glasgow.

368. You wish, I understand, to make some statement with regard to your process?—I have devoted a considerable amount of attention for several years to the question of sewage,—as to the best means of disposing of sewage from water-closets, and as to the best means of collecting the excreta; and I have come to the conclusion that the best method of collecting the excreta is by the system known as the carbon-closet system, which is a modification of the dry-closets, so far, that charcoal is substituted for earth or ashes. One great difficulty of the dry-earth system is the large amount of useless material necessary to be carried in and out of the place of collection, and the next great difficulty is in the weakness of the manure. Another very important difficulty lies in the provision of the necessary earth. These difficulties are overcome by the use of charcoal. In the first place, considerably less than one-fourth of the amount of charcoal is sufficient. In the next place, the difficulty of procuring the material is entirely done away with by this process, because the mixed product is re-burned, the ammonia is distilled off, and the resulting charcoal can be used again. We commence with any variety of charcoal, but after the process has been in use for some time, the whole of the charcoal ultimately is derived from the matter itself. The charcoal so derived, of which there are full analyses in the various papers on the subject, which have been read before several scientific societies, and which are now in your hands, is very similar to animal charcoal.

369. You are now speaking of charcoal made from the residue itself?—From the excreta itself. That will be readily understood when it is remembered that the excreta is disintegrated bone and muscle, and mixed with the animal and vegetable dejecta, and therefore, to a large extent, it is very similar to animal charcoal, and almost as valuable. I should state with regard to the dry system, what I have frequently stated before, that we have this advantage over the advocates of a wet carrier, that they are limited to the use of water, while the advocates of the dry system have a large choice of deodorizers; and I have shown in the papers I have produced, that of all the deodorizers, perhaps the worst to choose is earth or ashes. All chemists who have examined the product of the earth-closet have been unanimously agreed with regard to its

great poverty in nitrogen. I have worked some time on this subject, and have published a paper in the *Chemical Society's Journal*, in which I have shown that whereas if you mix organic nitrogenous material with charcoal, it preserves the nitrogen for any time; but if you mix it with earth, from the time of the mixture the nitrogen gradually disappears. That is clearly shown in a number of the analyses in the paper before you, and it fully explains the poverty of that material. I may state, in regard to this particular city of Glasgow, that the city authorities send out, I think, 20,000 or 30,000 tons per annum of what may be called a valueless mixture of very valuable materials. They mix all the outcome of the city in one mass—a very stinking product it is; and it has to be got rid of at a very low price. After it has been used, you may see the pots and pans, and kettles and old iron, and things of that sort, strewing the fields all round Glasgow. Now, I think that this is very wrong. I think that these things should be kept separate. By mixing the excreta as they do with all the valueless material, material which would have value if it were picked out, they are obliged to dispose of an offensive manure at a very low price.

370. Do you know the price they get for it?—I think it is about 2s. per ton.

371. Do the parties who purchase it fetch it away from the yard?—Yes; I cannot give the exact price, but it is mentioned in one of the papers I have given in. In these papers I have gone into the subject so fully, that I do not wish to take up much of your time in entering more fully into details. With regard to sewage from the ordinary water-closet, I have worked upon that for a considerable number of years. About twelve years ago I exhibited the first filtration of sewage through charcoal, and I gave it up then, for a very sufficient reason. I found that although the charcoal most perfectly purified the sewage, and was capable of very prolonged use—so much so that I was unable in my experiment to exhaust it—it did not pay. The reason why it did not pay was because the charcoal retained scarcely any of the nitrogenous matter, and a company which has since started to make peat charcoal has, I think, found to its cost that that is correct. My own experiments, to which I have referred, were the filtration experiments at Bradford in Yorkshire. The effluent water was perfectly clear, but the manurial value of the charcoal was almost nil. I think, from my experiments, that the only way in which to treat the sewage is, in the first place, to precipitate it with lime, as was recommended by Dr. Frankland; and, in the next place, to filter the effluent through charcoal. But the filtration must be intermittent. Dr. Frankland recommends earth, but I believe if charcoal be employed, the proportion to earth will in the end be found the cheapest. Of course any experiment of the kind cannot be made to pay, but, I think, considering that the charcoal continues in use for a very long time, provided you give it only the organic material to remove, and provided the filtration is intermittent, then by re-burning the filter you could use the filter for ever, and it would be found in the end the cheapest method. The water would be improved afterwards for irrigation if it were required; because the action of the charcoal on the nitrogenous matter in the sewage is to convert it into ammonia.

372. Does it fix the ammonia?—It converts the albuminoid nitrogenous material into ammonia, and the ammonia passes off; it does not fix the ammonia. The effluent is a perfectly clear, colourless fluid, containing a little ammonia, but it is pure ammonia.

373. That is using it as a filter?—Yes. Using it in the dry-closet, it retains the whole of the nitrogenous matter. There are other products that come over in the distillation of the dry-closet material, which are fully specified in the analyses.

374. Do I understand you to be recommending the use of charcoal as a filter in preference to using it as a dry-closet?—No. I mean that wherever it can be introduced, the dry system is by far the best. The charcoal-closet is a much cleaner closet than any other, and is always perfectly free from odour.

375. Then you are only speaking of cases where charcoal might be used as a filter, but not that you propose that as the better plan?—Certainly not. I am only speaking of where the water-closet system must be dealt with. I mean that the bulk of the work should be done by precipitating with lime, so that the charcoal should simply have to remove the nitrogenous matter, which it does very thoroughly; and if it has no other work, re-burning it occasionally will make it last for ever.

376. In filtering through charcoal, and letting the ammonia go free, what becomes of the ammonia? Does it pass into the atmosphere, or does it go away in the water?—It passes away in the effluent water.

377. Would not the water, in the course of time, begin to smell again?—No, because the ammonia is pure ammonia; it could not decompose.

378. You think the water which passed through this filter of charcoal would not, after standing for a period, again smell?—No. I have a specimen of water now which was shown to the first Rivers' Pollution Commission, I think about twelve years ago, which is still as bright as ever, and it was in the Paris Exhibition during the whole of that very hot summer. It is quite impossible that it should deteriorate at all after the action of charcoal.

379. Then what do you expect to gain by the precipitation with lime? What is the object of that?—The object of that is to clear the sewage previous to filtration.

380. But are you aware that the matter so precipitated seems to have no value for manure?—I am aware of that.

381. Then what would you do with it, because there would be such an immense mass of it?—It has a small value. I think it is stated by Dr. Frankland to be worth about 6s. 8d. per ton.

382. I saw a large quantity of it at Leicester, large mounds of it at the works there, where they used the lime precipitate, and the burgh surveyor assured me that the farmers would not cart it away.—I think that will be found to be the case with every precipitate from sewage.

383. I tried it myself; I took some of it to my own place, and my gardener said he found no fertilizing matter whatever in it. That was also what was told me at Leicester, where I saw it in great masses, that the farmers would not carry it away.—So I have heard.

384. Of course that would create a great difficulty if the process were carried on on a large scale in a city of the size of Glasgow, because they would not know what to do with this precipitated matter?—Unless it were made into cement.

385. That has been a later proposal. I should like you to give me some information about the dry-closets. Is the carbon system your own invention?—Yes.

386. I have been looking at one or two dry-closets in this neighbourhood, and Mr. W. R. Smith informed me that the matter which was taken away from these closets was lying in large heaps somewhere,—I forget in what quantity, but he said it had not been used. Do you know the reason of that?—The reason is, that the apparatus for distilling it is not ready.

387. Then you do not propose to sell it as manure?—Not until the process is quite perfect. Supposing that we began with ordinary charcoal, the product increases about one-tenth by each re-burning, so that after a time it becomes the outcome of the dejecta itself,—the animal charcoal. Having arrived at that stage, the ammonia which is distilled off is mixed with it, and then it can be sold as a manure at about £10 per ton. That has not yet been fully carried out. I may mention that a company that is working it has got the whole town of Oldham. The whole of the town is under the process, but they have not yet begun to re-distill, because their works are not yet ready.

388. How long has this system been in operation in Oldham?—It commenced last July, but the works are not yet completed.

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389. Have they not begun to use the material at all?—No; they are storing it.

390. Could you sell those heaps that are lying in this neighbourhood, if you wished to sell them, as manure?—Yes; they could be sold as they are.

391. What would they sell for as they are per ton?—They would be worth about £3 per ton.

392. Then it is not because you cannot sell the material that you are keeping it, it is because you are reserving it for some further process?—It is to make it into a proper manure by completing the whole process, as laid down in the paper which I have handed to you.

393. You propose to take these heaps and burn them, and use them over again?—We distill them in retorts, and then mix the charcoal with the ammonia.

394. And you are reserving these heaps for that purpose?—Yes.

395. Then when you have made it into what you call proper manure, what do you expect that it will sell for?—It will sell for about £10 per ton. With regard to the dry-closets, I may mention that they are particularly valuable for large works. Great difficulties have been met with in using water in many of the works around Glasgow, and I may refer particularly to one,—the large ship-building yard of Messrs. John Elder & Company, where a large water-closet and a large charcoal-closet can be seen side by side.

396. I have seen them. I did not observe them very carefully, but I was at the works with Mr. Dewar, and I saw the buildings that had been put up, and the apparatus that had been provided there. Can you give me any idea as to the quantity of charcoal you would require for a given amount of population, say for 100,000?—The total outcome for 100,000 persons would amount to about 40,000 tons per annum.

397. Do you mean it would require that amount of charcoal?—No; it would require half that amount of charcoal.

398. Then for 100,000 persons, 20,000 tons of charcoal would be required for a year?—Yes; that is, if the whole of the urine is taken in. The total removal amounts to about the same as the ashes per house.

399. Would the total removal be 40,000 tons, as you have stated just now?—Yes.

400. Then, supposing you used 20,000 tons of charcoal in one year, you would have to remove 40,000 tons of residue?—Yes. In the table which you will find in one of the papers I have given in, there are the figures on that subject which are given by different authorities, and you will find that these authorities differ greatly in the quantities. They vary from 20,000 to 45,000 tons a year.

401. Does the table give the price of the charcoal?—Yes.

402. I see that reference is made in the report of the Rivers' Pollution Commissioners to the use of charcoal made from sea-weed, and they speak of its beneficial effects when so made. Is it a necessity that the charcoal should be made from sea-weed?—No. That is the charcoal we begin with, simply because we are manufacturers of it, and it is cheapest.

403. Then it is not because you consider it has any advantage over other charcoal that you use it?—It has a great advantage over all other charcoals except animal charcoal, inasmuch as its composition is more like charcoal from the animal than from the vegetable—the sea-weed from which it is made lying just at the boundary-line of the animal kingdom.

404. By animal charcoal you mean charcoal made from bones?—Yes.

405. Do you know what the sugar refiners pay for their charcoal?—They pay, I daresay, £12 per ton for their best charcoal.

406. What do you get for your sea-weed charcoal?—About 30s. a ton.

407. You can make it for 30s. a ton?—Yes; of course that is less than its manurial value.

408. Where are the works for making this charcoal from sea-weed?—At Dalmuir.

409. What is the name of the Company?—The British Sea-weed Company.

410. Is that charcoal made for any other purpose than for matters connected with sewage?—It is used as a general deodorizer.

411. I think you said that ashes do not act well as a deodorizer?—Yes.

412. On what is that opinion founded?—In the first place, both earth and ashes act simply as deodorizers so long as they are driers. Unless the mixture becomes perfectly dry, it becomes putrid.

413. But, dealing with ashes first,—and I wish to direct your attention to that, because I have seen some works where they are using fine ashes in some of these dry-closets,—and assuming that the ashes are dry, what is to prevent them acting as a deodorizer?—They do act as a deodorizer if in sufficient quantity, but then the quantity required is large.

414. What quantity would be required as compared with charcoal?—Compared with charcoal, I should think the quantity required would be at least six times as great.

415. Would it be as large as the quantity of dry earth?—It would require more than dry earth, and the mixture, judging from the analysis of earthy mixtures, would constantly deteriorate in value.

416. Do you mean that it could not be used over again?—No; I don't mean that. I mean, with regard to earth, that when the product comes out from the closet, if it is kept for any length of time, it loses nitrogen, I believe in ammonia.

417. But suppose it was put on pretty speedily, that would not signify?—It would not.

418. I wish you to confine your attention to the ashes, because that is more important for works such as print works and others, where they have, perhaps, 500 or 600 hands employed, and where they have plenty of ashes; in such a case, of course, it is a very convenient thing to use up the ashes for that purpose, if they are useable; and the objection to it in your mind is, I understand, simply that if the ashes are allowed to remain, the ammonia would be dissipated in the atmosphere?—That is one objection, but I have a further objection, which is this, that if you wish to have a valuable manure, where you have to remove these substances, it does not seem right to mix it with six times its weight of valueless material, and to take the whole of it away. It is much better to mix it with a small quantity of a material which retains its value in the manure. I mean that even if you had to use animal charcoal, you would get a price for the manurial value of the charcoal when it came out in the manure, and therefore it would pay better to use the best charcoal rather than to use ashes.

419. Take the case of a manufacturer who has print works beside some of the rivers up the country; do you think it would pay him to buy charcoal rather than to use ashes from his own works?—I think so.

420. The cost of taking the ashes away in the manure would not signify very much, because they would be obliged to take them away in any case. At present they throw them into the river, but if they were prevented from doing that they would have to take them away?—If they could find immediate use for them on the neighbouring land, the ashes might be the cheapest, but ashes are not a good thing to put upon a soil unless it happens to be a very stiff clay soil.

421. My reason for asking you these questions about ashes is, because I rather understood Mr. Smith to say that the use of ashes led to the formation of some very mischievous gases. In fact, he almost left the impression on my mind that you should give up using ashes for the dry-closet altogether, and the idea, I must confess, was new to me.—That would only occur where the ashes were used in insufficient quantity. Almost any mineral would be a deodorizer, as ashes are, provided you use enough of it.

422. Then you are not afraid of the ashes and soil being apt to generate noxious gases?—Not at all.

423. Suppose that charcoal came to be extensively used in large towns and other places, would not that lead to an increase in its price?—This process would prevent that, because in working a large town you be-

gin with a certain portion of charcoal, but you re-burn that at the end, perhaps, of the first week, and you gradually provide the whole city with charcoal of its own manufacture; and having once supplied the whole city, you have daily balances of charcoal for sale.

424. Have you formed any opinion as to the extent of retorts that you would require? Does that appear in any of the pamphlets you have given in? For a population of 100,000, for instance, what amount would require to be expended in the shape of retorts?—That appears in the paper.

425. Does it also give the outcome?—Yes. I think the outcome of Oldham would be about 20,000 tons.

426. What is the population of Oldham?—I think it is about 80,000. The pan system is in use there.

427. What do you call the pan system?—The system of carrying away the excreta in pans, which is adopted a good deal in Lancashire.

428. Is the proposal in Oldham to apply this system to the whole sewage of the town—that is, to what is called the house sewage as well as to other kinds of sewage?—Not at present. They have no difficulty in Oldham with their house sewage. They are extremely well satisfied with the pan system; but they were met with this difficulty, that having carried the stuff away from the houses they could not dispose of it, and it became a very difficult matter to get rid of it. At present it is carted to these works and mixed with charcoal.

429. What do they do with their house sewage?—I believe that probably it runs into the nearest river, but I don't know about that. I only know that they have no difficulty with regard to it.

430. Do you know the expense of the application of this system to Oldham?—The company receive exactly what it was costing the corporation to remove the sewage; that is all.

431. Do you know how much that is?—About £3000 a year.

432. What do they do for that? You say the company are not dealing with the closets?—Not at present; but they propose to introduce that.

433. What is done by the company for that £3000 a year?—They simply act, as the town did before, as scavengers in taking away this material.

434. They take it away from the houses and mix it in the yard, or wherever it is?—Yes; supplying fresh pans.

435. And they then dispose of it in the best way they can?—Yes.

436. Which company is it that does this?—The Carbon Fertilizer Company.

437. Where is their office?—In Palmerston Buildings, Old Broad Street.

438. Have they a secretary?—Yes. I think his name is the Hon. H. C. Ponsonby.

439. Is that the same company that has to a limited extent applied the system in Glasgow?—Yes.

440. But I suppose the system has not been carried to any great extent in Glasgow?—No. It has merely been experimental here. I may say that this is the only safe process that can be applied to an hospital for infectious diseases, because if a retort is fitted up on the premises, there can be no further fear of the malaria extending beyond the hospital.

441. What are the retorts like? Are they like gas retorts?—Probably the best kind may be found to be vertical retorts, similar to those used in the shale works.

442. Do you mean in the shale works in this neighbourhood?—Yes; but that is merely a question as to the most economical retort for firing purposes.

443. Have you any knowledge or experience of the value of shale as a deodorizer after the oil has been extracted from it?—I only know that it does act as a deodorizer, as a filtering medium. It contains alumina and carbon, and that would make it a pretty efficient deodorizer.

444. We have been furnished with two specimens (showing the two bottles produced by Mr. Carrick, and which had been experimented upon by Mr. Coleman); one is of sewage previous to being filtered, and the other is a specimen of the water after it has been filtered through the crushed shale. We have been told that this water, which is perfectly clear, has been standing for several months in that state, and it appears to have no smell. If that be so it ought to be a very valuable deodorizer, because I know that several other deodorizers, although they have left the water clear for a time, yet it began to smell again. Are you aware whether crushed shale has been applied as a deodorizer to any extent?—I believe not. That specimen was brought out a few months ago by Mr. Coleman at a meeting of the chemical section of which I am president; and he made a statement about it which I heard. That is all I know of it.

Edward C. C. Stanford.

445. Is there anything more you would like to add?—I wish to say that in speaking of lime precipitation, I referred to house sewage, excluding rainfall. That would materially alter the character of the precipitate. I forgot that when answering your question about the precipitate at Leicester.

446. You only propose the lime precipitation to apply to house sewage?—Yes.

447. When you say that that would materially alter the character of the precipitate, do you mean that it would make it better or worse?—I mean that it would make it more valuable.

448. You mean that lime would make the precipitate from house sewage more valuable than what they got at Leicester?—Yes; because in keeping out the rainfall you would keep out the road dust and the detritus from the streets. It would then be almost entirely organic.

Mr. J. I. Coleman, F.C.S., Bath Street, Glasgow, and Chemist to Young's Paraffin Light and Mineral Oil Co.

J. I. Coleman.

449. I shall be glad to hear any explanation you have to give us with regard to the experiment you have made.—I was induced to make the experiment from the fact that shale, after the oil has been extracted from it, gives a residue which is raked up from the bottom of the vertical retorts used in distilling the oil, and that residue contains a considerable proportion of carbon or charcoal, united with the earthy matters of which shale is largely composed. I suspected that, containing such a large proportion of carbon, and the carbon being in such a state of minute division, it would act as a deodorizer; and I made the experiment simply by filtering the sewage through a layer of crushed shale about 3 inches in thickness. I had noticed that, in filtering sewage through deodorizing materials, the smell frequently returned a few days or a few weeks after the sewage had been filtered, and therefore I put these samples together, at the temperature of an ordinary office, for some weeks, in order to see whether or not the smell did reappear after filtration. I was surprised to find that the filtered liquid remained perfectly odourless, whereas that which had not been filtered smelt very strongly, not of sewer gas, but of sulphuretted hydrogen. I was led to suspect then that the real cause of the smell of the river was very possibly the reaction of the organic matter upon the sulphates in solution; and I thought the thing so interesting, chemically, that I drew up a short note and showed the samples to the chemical section of the Philosophical Society of Glasgow. Of course it follows from these experiments on refuse shale as a deodorizer that it could be applied to the solid fæces as well as to liquid sewage; but I have not made any experiments on the subject in that direction, nor have I prosecuted the experiments any farther since the results which I have now described to you were submitted in that short paper to the chemical section of the Philosophical Society. It was not my intention to give any special evidence on the subject before you, but happening to be in the room when it was mentioned, I am

J. I. Coleman.

glad to have this opportunity of answering any questions which you may put to me.

450. Has the note which you read to the Philosophical Society been published?—No; it was a mere verbal communication. It has not been published yet.

451. Was the statement you made nearly to the same effect as you have made now?—It was to the same effect.

452. Was the clear water, which of course is now without smell, left exposed to the air?—No; it was kept corked. Both bottles were kept tightly corked, and they were under the influence of light.

453. Don't you think it would have been better if you had left them exposed to the air?—In that case I think the experiment would have been less satisfactory, because any gas that might have been formed would simply have escaped. The gases proceed from internal decomposition, and not from any external action.

454. However, you did not try that?—No; I did not try it.

455. Of course, if the filtered water had been left exposed, you think the result would have been the same, and that it would not have had any smell?—I think so. The consequence of the exposure of a small quantity of liquid like that would likely have been the loss of smell in both cases in a short time, probably in a few weeks. I may state, further, that the sewage on which I made this experiment was got from Mr. Carrick in a two-gallon jar. That jar was left in the basement storey of a building, where the temperature would probably be about 50° Fahr. The samples in the two bottles which have been produced lay side by side in a place where the temperature was probably about 65°, or an ordinary office temperature, and they were exposed to the full light underneath a skylight. But it is curious to note that the smell from the stuff in the two-gallon jar, which was kept in a temperature of about 50°, remained pretty sweet; whereas the identical liquid, when freely exposed to the light and in a temperature of 15° higher, developed the strong smell that you notice in the sample. Therefore you have there the result of the action of warm weather, and possibly also the action of light, although that is a question which requires further investigation; but at any rate you have there the conditions which exist for sewage commencing to smell after it has entered the river, either by the action of light, or by the action of light combined with heat; and you have it further shown that these conditions can be removed by filtration through carbonaceous shale.

456. Do you mean that sewage corresponding to the sewage in the bottle, which is black, will not, when kept in a cooler temperature, smell like the specimen before us?—Yes. If it is kept at a temperature of 50°, or between 40° and 50°, it does not smell materially; but if it is kept at a temperature of 60° or 70°, a smell is developed; and the smell is not the smell of sewer gas, but it is the smell of sulphuretted hydrogen.

457. What is the composition of sewer gas as compared with sulphuretted hydrogen?—Sewer gas contains what is called albuminoid ammonia; that is, the ammoniacal vapours combined with organic nitrogen, which have a very wonderfully prejudicial effect upon the health; whereas the sulphuretted hydrogen is a chemical gas of a simpler character, which is certainly of a depressing character to breathe continuously, but is not of that poisonous, contagious nature which the sewer gas is.

458. But still it is deleterious to health?—Yes; sulphuretted hydrogen is deleterious to health, and it is very deleterious to metal, such as the copper sheathing of shipping, and it is very disgusting in smell.

459. In short, it has the smell of Harrogate water?—Yes.

460. Which paraffin works are you connected with?—I am connected with the works of Young's Paraffin Light and Mineral Oil Company (Limited).

461. Where are these works situated?—At West Calder and at Bathgate.

462. Can you give me any information as to the refuse which you make at the paraffin works? What is the residue that is passed away generally from paraffin works?—The only residue that may be considered a waste is the carbonaceous shale, which I have been speaking about.

463. Is there any liquid residue?—A considerable amount of water is used in distillation, in condensing the oil vapours, and also in washing, which may be considered waste unless it is used over again.

464. But is anything run away from the paraffin works into the stream or river which cannot be utilized? Do you at these works take any means of utilizing the liquid products of the works?—All the secondary products produced in the distillation of oil, which are the tars and the chemicals used in the treatment of the oil, are recovered. The tar is recovered and sold, either in the form of pitch or grease. The soda which is used in the refining of the oils is recovered by a process on the spot, and is used over again. The acid is also recovered, and used over again, so that the only thing that is wasted in oil works is any small quantity of oil which may accidentally run away in contact with the water.

465. I don't know whether you can answer this question or not, but what would be the effect upon the paraffin works, suppose it were enacted that they should not discharge into a stream anything which tended to foul the water? Could that be complied with generally?—My opinion on that matter coincides with the opinion which has been already expressed by Professor Frankland in the report of the Rivers' Pollution Commissioners, that it would be an unjust thing to require total freedom from manufacturing impurity either in this or in any other manufacturing operation, and that a standard of contamination should be allowed. I think if that is not allowed, it is a serious injustice to the manufacturers, and it is virtually so serious as to interfere with the progress of the trade or industry.

466. Still, I understand you to say that a very considerable portion of the products of this manufacture is recovered and utilized?—Yes.

467. There was a statement made the other day by Mr. Smith, when speaking of paraffin oil works in the middle of Scotland, to the effect that it was proposed, as a last resource, to build a drain extending probably thirty or forty miles to the sea, and that the products of paraffin would be found thirty miles from the works. Are you aware of any such project as that—to make a drain thirty or forty miles to the sea?—I may explain that such a project has been talked of, but since then, owing to legal action having been taken on the part of the riparian owners in the vicinity of these works, such steps have been taken, under the guidance of a chemist appointed by the Court of Session, as are at present, I believe, satisfactorily preventing complaints.

468. When were these alterations made?—During the course of this year.

469. Who is the chemist?—There are two or three chemists. Professor Crum Brown was one of them. There was a referee appointed by the Court. Mr. Pattinson, of Newcastle-on-Tyne, and Professor Crum Brown have had to do with it, but I cannot say exactly who the referee is now.

470. I understand that the shale which you used in this experiment was simply the shale raked out from the retorts, and then crushed?—Yes.

471. You had no other process?—No.

472. I suppose that shale would be a thing which could be supplied at a very low price?—Yes.

473. What do you do with it now?—It is simply put into heaps. It is perfectly useless. It has been tried, practically, for filtering water, and it has been used in our own premises for some time for that purpose, and is very efficient.

474. How do you suppose it would act if it were applied in one of these dry-closets instead of charcoal?—I am of opinion that it would be an efficient deodorizer; perhaps not as efficient as charcoal itself, but approximately so. It might very easily be tried.

475. What would be the carriage of it per ton to Glasgow?—I think about 5s. per ton.

476. What is the distance from Glasgow to Bathgate?—About thirty miles.

477. What is the distance from Bathgate to the sea?—I think about twenty miles.

478. I think this might be made a very valuable thing; but you would, possibly, require more experiments on it?—There would be no difficulty in making a few more experiments on the subject.

HUGH SHARKIE, Bottle Blower, Garngad Hill, Glasgow, examined. *Hugh Sharkie.*

479. I have long considered this question of the bad state of the river Clyde, and after much consideration, I have thought of a remedy; but previous to stating that remedy it would be well to state my opinion with regard to the evil which the present condition of the Clyde produces. I think the best way in which I can do that is by using a simple illustration. If you wish to empty a bottle, you raise the bottom of the bottle above the mouth, so as to get quit of the whole of its contents. If you wish to get out only the pure liquid from the bottle, and retain the sediments and impurities in it, you then keep the bottom of the bottle a little below the mouth, and so get rid only of the pure liquid. And just the same with the Clyde. If we take the surface of the water at Greenock, when at low tide, as the mouth of the bottle, and the bottom of the Clyde here at the Broomielaw as the bottom of the bottle, then we have a difference in level of about 10 or 12 feet. Give sufficient space at low water for the sediments or impurities still to remain in the Clyde after the tide has passed out; and the plan that I was thinking of was to adopt a means to force the impurities or impure water from the harbour by retaining a sufficient quantity above the weir, by raising the weir as high as it was convenient to do without injury to the surrounding property; then when the water was let down into the Clyde, you could at the same time have pipes running along each bank, so as to force up the impure water from the bottom of the Clyde, and before the water was allowed to go down into the harbour.

480. You propose to retain the water above the weir?—Yes.

481. Are you aware that there is an Act of Parliament in existence at present for taking the weir away?—Well, that would do away with that thing.

Mr. JAMES ROBERTSON, Engineer, Glasgow, examined. *James Robertson.*

482. I have not very much to say on the subject, but I read a paper at the Sewage Association some years ago, describing a system of separate pipes for water-closets, etc., leaving the main drainage as it now is, and having intercepting tanks, and taking it away in barges. With regard to the sewage question, I think that Messrs. Bateman & Bazalgette's report is probably the best; but what I wish to bring under your notice is a system of cleaning out the tanks which I proposed should be formed. At present I am lifting sand and sinking cylinders at the docks, on the principle which I would advocate for cleaning out the tanks. It is done by a system of jet-pumps. I force the water through a nozzle, and draw up the sand, and deliver it about 45 feet above the bottom of the place where it is taken from. I propose to empty the tanks and clean out the sediment in the same way. I likewise have another system of cleaning the tanks by centrifugal pumps. I now produce a printed description of the mode in which I am at present sinking the cylinders, and which could be applied to the cleaning of the tanks.

483. Are you using that method on the Clyde just now?—Yes.

484. Instead of Milroy's method?—Yes.

485. Do you find it better than Milroy's?—It is quicker. We can take up a ton of sand in a minute by a 4½ inch pipe. I also produce a plan showing the method of doing it by centrifugal pumps, which will be interesting to you at least mechanically. I have only made one or two of these. It has only recently come out, but its object is the same. (The witness described the plan which he produced.)

FRIDAY, 21*st May* 1875.

Mr. JOSEPH LINDSAY WATSON, Treasurer of Police, examined. *Joseph Lindsay Watson.*

486. I now hand in a statement, showing the cost of the cleansing department of the city of Glasgow, for the three years ending 15th May 1874:—

'*Statement showing the cost of the Cleansing Department of the City of Glasgow for three years, ending 15th May* 1874.

'Year ending May 15, 1872.			
Expenditure,	£41,051	15	9
Receipts,	23,847	10	0
Expenditure over Receipts,	£17,204	5	9
'Year ending May 15, 1873.			
Expenditure,	£46,275	10	8
Receipts,	17,493	6	7
Expenditure over Receipts,	28,782	4	1
'Year ending May 15, 1874.			
Expenditure,	£56,638	7	1
Receipts,	21,094	19	3
Expenditure over Receipts,	35,543	7	10

'Correct—JOS. L. WATSON,
Treasurer.'

I also produce the three following statements prepared by Mr. Waters, at present inspector of cleansing:—

'*Scavenging Department.*

'*Statement showing the number of Men employed, and their weekly wage, for fortnight ending 19th May* 1875.

'Sweeping Streets—		
Inspectors and Foremen, 1 at 30s., 1 at 28s., 1 at 27s., 1 at 25s., 7 at 24s., 13 at 21s.—	24	
Sweepers, 99 at 18s., 17 at 17s., 33 at 16s., 2 at 15s.—	151	
	—	175
'Close Washers (with hose)—		
Pipe Maker, 26s.—	1	
Washers, 1 at 20s., 1 at 19s., 1 at 18s., 1 at 17s., 2 at 16s.—	6	
	—	7
'Cleaning Private Streets and Courts—		
Sweepers, 1 at 19s., 208 at 18s., 7 at 17s.—	216	
Broom Makers, 1 at 19s., 4 at 18s.—	5	
Clerk, Storekeeper, and Assistant, 1 at 37s., 1 at 30s., 1 at 25s.—	3	
Urinal Painters, 2 at 20s., 1 at 18s.—	3	
Night Watchman, 19s.—	1	
	—	12
'Sanitary Department—		
Fumigaters, 25s.—	23	
	—	—
Carry forward,	23	410

Joseph Lindsay Watson.

Brought forward,		23 410
Clothes Washers, 1 Foreman at 22s., 11		
Women at 16s.—	12	
Van-drivers, 25s.—	3	
	—	38
Total,		448

'THOMAS WATERS,
Inspector of Cleansing.'

'Correct—JOS. L. WATSON,
Treasurer.'

'*Cleansing Department.*

'*Statement showing the number of Horses employed during fortnight ending 7th May* 1875.

'Night,	63
Day,	73
Sundry work, watering, etc.,	20
Sick and unfit for work,	4
Total,	160

'THOMAS WATERS,
Inspector of Cleansing.

'Correct—JOS. L. WATSON,
Treasurer.'

'*Cleansing (Manure) Department.*

'*Statement showing the number of Men employed, and their weekly wage, for fortnight ending 19th May* 1875.

'Night Duty—		
Foremen, 1 at 40s., 7 at 28s., 4 at 26s.—		12
Wheelers, paid by weight, received £116, 14s. 3d., showing an average of £2, 18s. 4¼d. per man per fortnight—		40
Carters, at 25s.—		63
„ Foreman, at 30s.—		1
Stagfillers, at 20s.—		8
Gateman and Stablemen, 1 at 22s., 2 at 21s., 1 at 25s., 1 at 24s.—		5
Depot Foremen, 2 at 25s., 4 at 24s., 2 at 20s.—		8
Depot Labourers, at 18s.—		25
Soil Men, at 25s.—		10
		—172
'Day Duty—		
Carters, 76 at 25s., 5 at 24s.—		81
„ Foremen, 1 at 30s., 1 at 26s.—		2
Depot „ 1 at 30s., 3 at 26s., 2 at 25s., 3 at 24s., 1 at 23s., 1 at 22s., 4 at 20s.—		15
Depot Labourers, at 18s.—		55
Cartwrights and Waggon-builders Foreman, at 45s.—		1
Cartwrights and Waggon-builders, 6 at 32s., 1 at 29s., 1 at 27s., 1 at 25s., 2 at 23s., 1 at 22s., 1 at 20s.—		13
Blacksmiths and Horseshoers, 1 at 39s. 3d., 1 at 35s., 2 at 32s., 1 at 31s., 3 at 30s. 9d., 1 at 26s. 6d., 2 at 22s.—		11
Saddlers, 1 at 32s., 2 at 26s.—		3
Yard and Stablemen, 1 at 27s., 4 at 25s., 1 at 24s., 1 at 23s., 4 at 22s., 4 at 21s., 4 at 20s., 2 at 18s.—		21
Labourers, 1 Foreman at 26s., 9 at 20s., 24 at 18s.—		34
Sale Office, 2 at 32s., 1 at 24s., 2 at 20s.—		5
Office-cleaner, at 7s. 6d.—		1
Slaughter-houses, 1 at 30s., 1 at 22s., 6 at 18s.—		8
		—250
Total,		422

'THOMAS WATERS,
Inspector of Cleansing.'

Correct—JOS. L. WATSON,
Treasurer.'

Mr. A. G. THOMSON, C.E., 194 West George Street, recalled.

487. I wish to put in the following statement, in addition to the evidence which I gave before you at a previous sitting:—

'194 WEST GEORGE STREET, GLASGOW,
May 19, 1875.

'To Sir John Hawkshaw, H.M. Chief Commissioner, Clyde Purification Commission.

'SIR,—In reference to the scheme I had the pleasure of bringing before your notice on Monday, I ask leave to submit a few amendments and explanations, partly suggested by your remarks.

'On Sec. 4. In separating the rainfall from the sewage, it would be better to make use of *existing sewers* to carry off the rainfall, and to have a new set of well-laid glazed pipes, of moderate section, for the sewage water. Although it is desirable to minimize the quantity of matter to be treated, the amount of water used for flushing must still be amply sufficient to cause a steady flow. Receivers at termination of intercepting sewers to be furnished with filters, through which part of the water can be drained off comparatively pure.

'On Sec. 9. The term "retort" is perhaps scarcely accurate as applied to designate the vessels within which I propose to subject the sewage water to *chemical action* by sodium, etc. This action is by no means of the nature of that produced by heat on dry materials in gas or other retorts; and the *water* contained in the sewage is a necessary element, yielding, by its decomposition, the oxygen necessary for the entire combustion of the remaining constituents.

'I should be happy, if so instructed, to prepare plans for such apparatus as would be required to test the practical application of the scheme.—I remain, your obedt. servant,

'ALEXR. GEORGE THOMSON, C.E.'

Mr. WILLIAM WALLS, Refining and Manufacturing Chemist, Glasgow, examined.

488. You are a member of the Town Council of Glasgow?—Yes.

489. And you have been one of the Bailies of the city?—Yes. I am also a Justice of Peace for the county. I propose to state what my experience has been with regard to the process of refining spermaceti. In 1851 I commenced operations in that direction in Glasgow, and I was the first to do so. I continued the work in the usual way, as it has been done in London, till 1871. I knew, of course, by that time, that there was a considerable quantity of refuse from the works put into the drains.

490. From chemical works?—Yes, from the chemical works. I accidentally found, on opening the drains, that there was a considerable precipitate or deposit there of valuable stearic acid or spermaceti.

491. You found that in the ordinary drains?—It was in the ordinary drains passing through my own premises. I immediately directed my attention to the matter, in order to ascertain the cause of that precipitate or leakage; and I found that by keeping back the sewage—I do not know whether I should call it sewage or liquid refuse—but I found that by placing it in a vessel lined with lead, and then treating it with sulphuric acid, keeping up a moderate temperature and considerable agitation, I got in the morning a large and valuable cake of spermaceti on the top of the liquid.

492. This refuse you speak of was refuse from chemical works?—Yes; refuse as the result of the refining process. I may mention that during the first year that I kept back that refuse I preserved it all, and found that in value it was quite equal to £800 for one year.

493. And previous to that time this had been running away?—Previous to that, and from the year 1851, it

had all been going into the sewers and down to the Clyde. I do not say it had been done to the same extent in the previous years as in the year I speak of, because that was a year in which we did a larger business than usual; but I have no doubt whatever that from 1851 onwards we had been sending into the sewers the equivalent of from £300 to £400 a year. That is now, I believe, entirely stopped; because, on examination, the liquid, after having been treated with sulphuric acid, is perfectly clear.

494. Is this process you refer to carried on at most of the chemical works?—It is carried on at all the chemical works of the same nature as my own. Wherever oleac or stearic acid is treated with alkali there must be a very serious loss of the oleac or stearic acid, because the alkali will not go away without taking its fill of it. It is like a sponge dipped in water. Directly the alkali meets with the oleac or stearic acid, it takes a large portion away; and it will not give it up until it has been treated with acid.

495. It will not give it up, in short, until it is made to do so?—No; and the acid makes it discharge it. The mechanical apparatus used in the process is a small leaden vessel, arranged in such a way as that the liquid shall at all times be drawn off from the bottom of the vessel. It is quite an open vessel. The outlet would be from a pipe taken from this point (showing), and conducted into the drain.

496. You use a syphon?—It is almost a syphon; but it is only when the liquid is above the top of the discharge-pipe that anything can get away, and you will see the object of that at once; that nothing but the heavier portion of the water can get away. So long as there is any light oleac or stearic acid, it remains on the top of the liquid, and continues subject to the chemical treatment I have named.

497. Then in that tank you put what?—All the refuse from the refinery is collected in that tank.

498. And what acid do you treat it with?—Sulphuric acid.

499. None of your refuse escapes without that treatment?—None whatever. Nothing can escape except the ordinary water which really is not refuse, because whenever we use chemical liquids, all these chemical liquids are collected in this vessel and treated there.

500. I assume that the process pays, otherwise you would not adopt it?—It costs almost nothing to do it. The sulphuric acid is of very small value, and the vessel in which it is collected is a thing that costs £20 or £30 perhaps, not more.

501. Then of course it pays?—Yes.

502. And it is worth the while of the manufacturer to recover this?—Yes; it will pay itself in less than a month.

Mr. DAVID ANDERSON, Ironmonger and Weighing-machine Maker, 93 Stockwell Street, Glasgow, examined.

503. The witness read the following paper:—

David Anderson.

'So far back as 7th October 1857 and July 1858, the *Glasgow Herald* kindly inserted two letters of mine, on the best plan for utilizing the sewage and the purification of the river Clyde.

'After such a length of time I expected there would, on the present occasion, have been brought before you some original and ingenious principle for carrying out this long desiderated improvement; but seeing that almost all the proposed plans have been suggested many years ago, I am induced to bring before you my plan.

'I proposed that the old waterworks at Dalmarnock, where at that time there were powerful steam-engines and extensive reservoirs, should be taken advantage of for my proposal, which was, that by intercepting sewers on both sides of the river and running parallel with it, and as far down as might be deemed necessary, the sewage thus intercepted could be led up the river instead of down, and falling into a large tank, be then pumped into the reservoirs, and, after simple precipitation or otherwise, purified; the clear water could be run into the river, when the residuum could be treated in various ways, and be mixed with the now comparatively useless ashpit contents, carted for the purpose, and thus converted into good and profitable manure.

'I have read of many plans, and some of them are now brought before you, such as having receptacles with perforated bottoms covered with ashes and charcoal, and the water-closet pipes running into such; the water thus cleaned would then be run into the sewers, and the residuum to be used for manure. This plan I consider good in its way, but it would be expensive, costing, as the proposer says, so much as £30 for two closets. By my plan the same thing could be done at less cost; seeing the sewage would be conveyed to one place, it could thus be much easier purified, and otherwise manipulated in quantity, than by so many thousand small receptacles.

'If the dry-closets had been introduced before water-closets, this plan I daresay might have done well enough in small towns, but for such large places as Glasgow it would be troublesome and expensive, so that I think it would be too late now to change to such a principle.

'Messrs. Bateman & Bazalgette's proposal to send the sewage to the sands of Ayrshire I considered to be very comprehensive, but by far too expensive to cost so much as £3,000,000 sterling.

'I think that by my scheme being partly used as at first proposed, and by means of the same steam-engines to be erected, the sewage could be forced by pumps to, say, the top of Cathcane Braes; it could be conducted then by gravitation, in pipes or open drains, to all the level grounds in the Vale of Clyde, or to the Strath of Renfrewshire, and so all the farms in these districts could be irrigated at a very cheap rate to the farmers, and profitable to Glasgow.

'I have no pretensions to be an engineer or a man of science, to be able sufficiently to explain how my scheme could be carried out; but when it was at first proposed by me it was approved of by many gentlemen of position, and even spoken of in the Town Council, although brought forward by a member of Council as his own idea; and the *Glasgow Herald* noticed it favourably. I believe my plan would cost somewhere about £400,000 or £500,000, being perhaps less than a sixth of the expense of Mr. Bateman's.

'If the distance to Ayrshire had been a good deal less, where there are so many thousand acres of waste sandy land, I have no doubt but Mr. Bateman's plan would have been tried long ago; but if my scheme were adopted, which I think equally practicable, and as there is plenty of land in the districts I have named within a few miles of the city, and porous, sandy land, capable of absorbing all the sewage, I have no doubt the farmers would gladly take advantage of both the sewage, as also the manufactured manure from the city ashpits mixed on the spot with the sewage. I hardly think it necessary to notice that the principle of irrigating land with sewage is by far the best and most natural fertilizer and purifier, as instance the meadow land of Edinburgh, which at one time was valueless, but now is worth from £20 to £30, and more, per acre. I am aware that there was an objection to feeding cattle from grass so produced, and that the sewage on the land was offensive to the smell. All this has been disproved in respect to anything hurtful to the cattle or their milk; and for smell, if any, sewage can now be rendered inodorous and innocuous.

'As I have already stated, I anticipated that some new idea would have been proposed to overcome the sewage difficulty, or else I would not have intruded my plan to your notice at present. It was only yesterday I thought of doing so; and therefore any inaccuracies or want of explanation I will be glad to correct or make more plain, if wanted.

David Anderson.

'I have just read a description in the *Glasgow Mail* of to-day of the sewage works at Coventry; and as it describes so fully the plan there carried on, I can't do better than refer you to such, as, in my opinion, the same principle is quite applicable to my scheme for Glasgow.'

504. I see you propose to take the sewage up the river. Have you considered what point you would take it to?—To Dalmarnock. Although the powerful engines that once belonged to the Corporation are not there,—at least they are used for a different purpose,—the reservoirs, which are very extensive, are still there; and to supply new engines is a thing that could easily be done in Glasgow. The distance to Dalmarnock from the Cross of Glasgow is not much more than two miles.

505. Where is the sandy land in the neighbourhood that you refer to?—Round about the Tollcross district, a distance of about three miles from here. There is an immense quantity of it there.

Councillor Dreghorn.

Councillor Dreghorn, Glasgow, examined.

506. I have taken a good deal of interest in this matter for the last thirty years, along with Mr. Morris Pollock, of Govan, who was impregnated with the notion that irrigation was the proper way of dealing with the sewage; and a few years ago I took up that scheme, and spoke about it to various people, among others to Mr. Myles, the factor for the Elderslie estates. I was saying to him that the proposal was to take the sewage down to Ayrshire, and to irrigate the land there with it; but he said that before it got the length of Ayrshire it would be taken up and utilized by the farmers on the line through which it went. He said: 'I know how it would be; and you may depend upon it that that is the way to deal with the sewage of Glasgow.' I have a number of papers and plans connected with the matter, but I thought it was not worth while troubling you with them. That, however, was the plan which Mr. Pollock thought was the correct one for utilizing the sewage, and he had studied the subject. He had been abroad; he had been in America a good deal, and I suppose he had seen the system in operation there. He is now dead, but I have some of his pamphlets and papers, which, if they would be of any use to you, I could send in. The proposal at that time was to convey the sewage across the river, just at the present jail, at the end of the Green, and then to send it down on the other side of the river.

W. R. W. Smith.

Mr. W. R. W. Smith, recalled.

507. I have to ask your attention, Sir John, to a statement from Mr. Joseph Wylie, who is now in attendance, and who called upon me this morning with an introduction from a gentleman in Glasgow. Perhaps you are aware, from the public prints, that we are at present in some difficulty with our cleansing department. This Mr. Wylie was formerly in the employment of that department, and had charge of the mixing of the manure; and, curiously enough, when talking to him this morning, the matter of the mixing of ashes and night-soil came up. I said to him, 'But we are not getting the price for the manure, because you must know as well as I do that the whole matter evaporates.' With this introduction I shall leave Mr. Wylie to tell you what he said to me in answer to that, and I have no doubt he will give you the fullest information.

Joseph Wylie.

Mr. Joseph Wylie, Contractor, Glasgow, and formerly employed in the Cleansing Department, examined.

508. We found on mixing ashes and night-soil together, that when not immediately covered up they evaporated into the air, and if they were kept open for a matter of twenty-four hours they were worth absolutely nothing. When the farmers bought the stuff from us, I used to tell them to put it down in large heaps, and cover it up with the top-dressing of their ground, in order to keep it from evaporating; and they found that was of great service in preserving it for use.

509. Then I understand you to say that this evaporation took place from the fact of the soil not being covered up with ashes?—If it was not covered up immediately it was laid down, either with ashes or with earth, it evaporated all at once.

510. Suppose it had been properly covered up with ashes, do you expect that it would then have lost the valuable properties of the manure?—The full strength of the manure would then have kept in for a considerable time; but by not doing so, it evaporates.

511. But suppose this manure was immediately covered all over with ashes, what would be your opinion of it then?—If it was immediately used on the farmers getting it, it would do a great deal of good, and they would then get the proper use of it; but if it was allowed to lie for a considerable time, it became of very little use.

512. How long were you employed in the Cleansing Department?—Three years. The manure did very well for six months if it was at once used, but after that it was of no use at all.

513. Do you mean that it would remain good for six months?—Yes; it would remain good for six months in the ground, if it was immediately used after being mixed.

514. Is it of no benefit to a crop after six months?—None whatever.

515. Have you ever known cases of injury to cattle by manure carried out of the town?—No; I never knew anything of that kind.

516. You never heard any complaints of that?—No; not further than that I have heard of pieces of leather being left amongst the manure, and the cattle sometimes choked upon them. When the fields came to be sown out in grass, the cattle went to these pieces of leather, whenever they could get them, and chewed them, and sometimes worried upon them.

517. Do you mean that cattle are fond of chewing leather?—Yes; they chew it, and after it has been a considerable time in their mouths, it goes down, and if they are not relieved, it chokes them.

518. What price did the farmers give for the manure?—When I was in the Department, we used to get 3s. 6d. per ton for it, but I believe they are not getting so much for it just now.

519. Did you carry it to them?—Yes; we sent it out in railway waggons.

520. Who paid the railway carriage?—The farmers.

Mr. Wm. Robertson, Civil Engineer, Glasgow, examined.

521. In 1868 I wrote a letter to the Lord Provost of Glasgow as to the purification of the river; and as Mr. Smith, whom I never met except in the discussion of this question, has handed you a copy of my pamphlet without my knowledge, I shall be happy to give you any explanation with regard to it which you may wish. (Produces copy of his pamphlet.)

522. Have you made any calculation of the quantity of water which you would have in this tidal reservoir?—It would hold about 250,000,000 cubic feet, but I only expect 150,000,000 to be available for flushing purposes each tide.

523. What is the size of the tanks which you propose to make?—The tanks would be sufficient to contain eight or ten hours' sewage of the whole town on both sides, and they could be enlarged.

524. What quantity do you take that to be?—It is mentioned in the pamphlet.

525. Have you made any estimate of the cost of this scheme?—No; I have made no regular estimate, but I jotted it down roughly at the time that it would cost about £600,000. The wall, instead of being built as shown there, might be a large embankment; and I propose that one water-channel might be in the reservoir, where small craft could always come up the river during the rising tide, and that would take them from the main channel between Port Glasgow to the Cart.

526. Did you assume in that estimate that you would have to pay anything for the land on the foreshore?—No.

527. You assumed no charge for the land?—No charge for the foreshore within high water-mark, but there are 20 or 30 acres of ground to be taken beyond that, for the purpose of giving a sufficient width to the channel near to the Cart.

528. But as regards the foreshore, between high and low water-mark, you assume that you would have nothing to pay for that?—Nothing. There would be no pumping required for the scheme, except that there would be a small subsidiary sewer along the river, to take the lower drainage up, and that would require to be pumped to the upper drain; that is, the drainage from the centre of Glasgow.

529. How do you propose to apply this scheme to the north side of the river?—The same as to the south side—by a large drain.

530. I see that; but how do you get the sewage from the tank on the north side to the reservoir on the south side?—This (showing a plan) is a pure-water reservoir.

531. But what do you do on the north side?—Just allow it to flow into the river, between high tide and low tide, and the water would wash down the sewage from both sides. The tidal reservoir would convey the pure water up to the tanks.

532. And you take it that it would wash down the sewage from both tanks?—Yes.

Mr. JOHN CHARLES MELLISS, Engineer of the General Sewage and Manure Company (Limited), 1 Crown Buildings, Queen Victoria Street, London, examined.

533. I believe you wish to give me some information with regard to the operations of your company?—Yes. I propose, with your permission, to give you some account of the work of the General Sewage and Manure Company, which has extended now over the best part of three years. My description will relate more particularly to the construction of the Sewage Works at Coventry, for dealing with, defecating, and disposing of the sewage of that city. I may say that the city of Coventry some three years ago was prohibited, by an order of the Court of Chancery, from polluting the river Sherburne. They had previously tried to filter their sewage through gravel and matters of that kind, and they spent a good deal of money in that way, but without any success. They then adopted the idea of taking a sewage farm, which was at that time, I think, perhaps almost the only way of getting out of this great difficulty; and I have been informed, on very good authority, that they purchased 282 acres of land, for which they paid £28,500; but when they went a little further into the cost of preparing that land, and draining it, and pumping the sewage on to the top of it (for I may say that some of it was nearly 100 feet high), and distributing the sewage over the whole of the land, they came to the conclusion that they would be involved in endless expense, and something they could not very well see their way out of. It was about that time that the General Sewage and Manure Company came forward, and undertook to defecate the sewage, and to relieve the city of expense; and that has been done in such a way that the Court of Chancery and everybody else has been satisfied. I may say that the works are precipitation works, and they are adapted for dealing with the sewage by a chemical process. If you will allow me, I will hand in a copy of a small pamphlet which I have just drawn up with the view of giving an account of my work in the matter of purifying sewage. This is the order in which the sewage is dealt with,—first of all, the grosser particles are strained out by a machine, known as Latham's Solid Sewage Extractor, so that the garbage, and all fæcal matter, and paper, and everything of that kind is taken out of the sewage, and it is brought into a cleaner condition for chemical treatment. The sewage is then dealt with by a chemical process, that is to say, sulphate of alumina in solution is added, and milk of lime is added, and precipitation is allowed to take place. The precipitate which takes place is daily converted into a portable form, because I have found from my own experience, extending now over several years, that although we would certainly be improving the condition of our rivers by purifying the sewage in that way, yet we might be creating a nuisance quite as bad by allowing the precipitate from the sewage to accumulate, and not to reduce it to a portable form, and get rid of it in some way or another. The fourth process, which is in operation in Coventry, is the filtration of the effluent water.

John Charles Melliss.

534. Is that done after dealing with it chemically?—Yes.

535. Then first you filter it, then you deal with it chemically, and now you are to give us the next process?—Yes. I perhaps might have taken up the processes in better order, but I find that in the pamphlet I have got them in that order. I might have taken them thus,—first, mechanical straining of the sewage; second, chemical treatment and precipitation; third, filtration of the effluent water; and fourth, reduction of the precipitate daily to a portable condition. I would here remark that the General Sewage and Manure Company in their works deal with the whole of the sewage of the town, amounting to two million gallons per day. It is not a mere experiment; the works are substantial works in every way, and every drop of sewage that comes from the town is dealt with. The population amounts to about 40,000. I may also say that we are under pretty strict supervision there; the municipal authorities keep a very close watch over us, to see that everything goes right; and I am happy to say that not only does everything go right, but everything has gone right for the last twelve months, so that I am speaking from experience. The sewage of Coventry is a very foul sewage. It is rendered very foul and costly to deal with because of the large amount of dyeing refuse from the silk-dyeing factories in the town. Sometimes it is as black as jet, sometimes it is bright blue, sometimes it is red, and sometimes it is other colours. With regard to the effluent water, I would say that a very small amount of land is used for filtering it. The proportion of land required is of course very small as compared with the large amount of land that would be necessary for filtering crude sewage. I find that 4½ acres are sufficient to filter the whole of the effluent water from the Coventry sewage, but we have prepared 9 acres as a filter, in order that we may be able to change our filter beds. When one has been used for a fortnight or three weeks, we change it for another, and then plough over the surface. I have for my own information had an analysis made of the effluent water by Dr. Voelcker, and I think it shows a very fair standard of purity. The analysis itself is given at page 14 of the pamphlet. It gives first the mineral matters, but when we come to the really injurious matter you will see that in the imperial gallon it contains only ·630 grain of free (saline) ammonia and ·042 grain of organic (albuminoid) matter. Dr. Voelcker's opinion with regard to it is as follows: 'The water contained a few flakes of suspended matter, which rapidly settled to the bottom of the bottle in which the water was received. It had no perceptible smell, and was almost free from colour; the residue, which was left on evaporating the water, was only slightly coloured yellow. The sample of effluent water contains but

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little organic (albuminoid) ammonia, and not much more than half a grain of saline ammonia per gallon. From this sample the nitrogenous organic constituents of raw sewage appear to have become oxydized and changed into nitrates to a very large extent.' I may here remark that I have myself kept fish in this water for two days without any effect being produced upon them, and many gentlemen whom I have had the pleasure of showing over the works have not only tasted it, but several of them I have noticed have even swallowed a small portion of it.

536. Can you give me any idea of the cost of the works?—Do you mean the cost of erecting our works, or the cost of working them annually?

537. I should like first the cost of erecting the works, and then the annual cost?—The works cost, I should say, about £14,000.

538. Is that including the land?—It is exclusive of land.

539. What do you call the annual cost of working?—I have got it before me in the form of an annual charge on the rateable property. A charge of 1s. per £ on the rateable value would cover the whole cost.

540. Do you know what the rateable value is?—The cost of working is about £5000 per annum, or perhaps I should say, as I am speaking from memory, between £4000 and £5000, for it is not quite £5000.

541. At any rate it does not exceed £5000?—No.

542. By what name is this process called?—Anderson's process.

543. You say that it is milk of lime and sulphate of alumina that are used?—Yes, sulphate of alumina and milk of lime.

544. Do you know anything about the works at Rio de Janeiro, where it appears to me that very nearly the same process is used?—I do not.

545. I have seen them lately, and they use sulphate of alumina and milk of lime there, and it occurred to me that the processes might be the same. Mr. Gotto is the engineer there, and I went over the works with him.—I was not aware that they were working the process out there.

546. They are certainly using sulphate of alumina and milk of lime. Whether they use something else or not I am not certain, but these two things I know are used at the works at Rio.—One great advantage that we have at our Coventry works is, that we manufacture a cheap sulphate of alumina there. We make the chemical there, so that we produce at a very moderate cost what, if we went into the market for it, we should have to buy at, I suppose, four or five times the cost.

547. Do you dispose of the precipitate?—We do.

548. What do you get for it?—I have had it analyzed also by Professor Voelcker, who is, I think, if not the best, at least one of the best authorities on the subject; and the material, his analysis of which is given at page 19 of the pamphlet, is worth from 30s. to 40s. per ton as a manure. It is not a high-priced manure, a matter to which I shall speak presently; but if it were not taking up too much of your time, I should like to give some little description of the process employed in our works.

549. I shall be glad to hear it.—I have already referred to the straining of the sewage, which is our first process. As it goes through the city it is strained by means of these extractors which I have mentioned. Then we manufacture the chemical on the spot; then we prepare a solution of the chemical by dissolving it, and then we add it to the sewage. The sewage and the chemical are thoroughly mixed together, as it passes through continuously. It then passes on, and a preparation of milk of lime is made in a similar way to the solution of sulphate of alumina, and then the whole of the mixture is stirred together again. This operation goes on constantly; as the sewage passes through a well, it is simply stirred round.

550. Can you give me the proportions of sulphate of alumina and milk of lime to any given quantity of sewage—say to a gallon?—I could not speak to that with certainty. I might be misleading you if I were to attempt to state that. Of course it varies very much at different hours of the day, according to the quality of the sewage; and that is a matter which we find, on practical experience, that it is better to leave in the hands of the working man. That seems a crude way of doing it, but I find in practice that it is better than any theory. He does it in this way: At a certain point he has glass test-tubes, with which he takes off a sample; and if he sees that precipitation does not take place quickly—and of course from practice he knows how quickly it ought to take place—he simply throws on more or less of the precipitating material. Then the whole mixture—that is, the sewage mixed with the sulphate of alumina and the lime—enters the precipitating tanks; and I find that that mixing is really of very great consequence. Many people have told me that I have a good deal too much machinery, but I do not at all agree with them, because I have tried it both ways, and I find that the thorough mixing economizes chemicals very considerably. We treat it as a continuous system—that is, we allow the treated sewage to enter at one end of the tanks as the effluent water is passing over at the other, so that the operation is going on continuously. By the time it has reached the end of our tank, subsidence has taken place sufficiently to allow a fine sheet of water to flow over a weir; and that water, as I remarked just now, we filter in the tank. I do not myself consider that it is absolutely necessary to filter it, and I think that wherever there is a large river, or wherever it goes into the sea, we shall probably find in time, from experience, that it will be made sufficiently pure to go into a large river or the sea; but at Coventry we have got a very small river,—a river that contains, generally speaking, about one-half the flow of the sewage itself; so that we have filtered the water there in order to make it come up to a high standard.

551. What do you do with the precipitate? Do you dry it?—Before coming to that, perhaps you will allow me to mention that there is an account of the works in the *Morning Advertiser*, which I did not meet with until this morning, and which I won't read through unless you wish me to do it, for it is a pretty long one; but it may be of interest to you. It has appeared in several other papers; it appears in the *Hour*, and it appears in the provincial papers published in the neighbourhood. This account which I met with in the *Morning Advertiser* this morning appears to me to give a tolerably fair description of the system. Now, having disposed of the water, I come to the precipitate or sludge. At present we work those tanks for a period varying from two to three days, and we have four tanks. I may say that we are always working three, while we are cleaning up the fourth, and so the process goes on in regular rotation. The precipitate or sludge which falls to the bottom is swept up by manual labour. We have found manual labour to be the best for this work, because it employs men who must be otherwise on the works. One of the chief features of our system is that we have very few men on our works. I don't think they exceed twelve or thirteen at any time, and at night we employ two men only. On Sunday, I am sorry to say, we are still obliged to keep our work going, but the labour then is reduced to a minimum, for there are simply two men on the premises to see that the engine is going. There is no work of preparation of chemicals or anything of that kind done on Sunday. Then the precipitate from the bottoms of the tanks is passed into an under-ground chamber, which is 3 feet below the bottom of the precipitating tanks, and there we have a means of drawing off any water that rises to the top. Of course the precipitation still goes on there; it consolidates to a certain extent, and we draw off the effluent water there by a very simple contrivance. There is a sluice in the side of the tank, with some holes and pins, and we pull out the pins in a downward direction. The sludge then contains,—of course it varies very much,—but I should say it contains about 90 per cent. of water, and perhaps often more. The sludge passes

from this under-ground chamber by a passage under our drying rooms, and it is there lifted pretty much in the same way as common dredging machines do. We first of all strain that mud, or, as it is commonly called, filter it (I think myself that straining is the better word for it); and it is done by a very ingenious patent machine,—the first one, I think, that has ever been made is now on our works at Coventry. I don't know that I can describe it very well so as to make myself perfectly clear to you. It is a large drum, about 8 feet in diameter and about 4 feet across, which revolves in a trough of sludge. The surface of it is covered first of all with a wire netting, and then with calico. As it revolves and dips into the sludge, the air is exhausted behind the wire netting and the calico, so that the mixture is sucked through, and a film of stiff sludge adheres to the face of it. As it goes round, the water passes out through the trunnion or axle, so to speak, of the machine, and is drawn away; the stiff mud is scraped off, and has then got to a much stiffer consistency. That seems perhaps to be an elaborate machine, and I thought so myself when I first heard of it; but after seeing it working, I have a much better opinion of it than I had at first, and we have adopted it. The mud, or sludge, or precipitate then passes into a drying machine, which may be tolerably well known by the name of Millburn's Patent Sludge Drying Machine, where heat is applied to it. It is there dried to a powder, and that produces the sewage manure (of which I gave the analysis just now from p. 19 of the pamphlet), worth about 30s. or 40s. per ton. But we have found from experience that although it is well worth that money to the farmer, who is naturally very shrewd and knows what he is about, he does not take very readily to a manure worth only 30s. or 40s. per ton. He argues in this way, 'If I can get a manure at £6 or £7 per ton, it will cost me so much more in proportion to cart your cheap manure than it does to cart that concentrated manure,' and therefore he very naturally does not like the cheap manure very well; but in order to meet that difficulty, we add fortifying agents—that is, other fertilizing agents—to the manure, sulphates of ammonia, phosphates, and other materials, so as to bring the manure up to any value that the farmer demands. In that way we find it meets a much more ready sale, and becomes much more popular. I have just now explained one mode of drying and of fortifying this manure; but the General Sewage and Manure Company have within the last week patented another mode of drying and of fortifying at the same time, which I think will lessen the cost of production, and be very much more satisfactory. It is a mode of drying the sludge without the application of artificial heat, or if heat is employed, a very small amount of artificial heat will do. I will explain the process in this way. The wet sludge is mixed with dry powdered phosphate of lime and sulphuric acid at the same time. Of course a great deal of the moisture, or most of the moisture, in that way is absorbed, and enters into chemical combination as water of crystallization; and after remaining for perhaps twelve or twenty-four hours it dries up the whole material, so that with the dry sludge we enrich the manure.

552. Can you give me the weight of the precipitate from, say, a day's sewage of 2,000,000 gallons?—Between 4 and 5 tons. That is perhaps a wide margin that I am giving you, but it is as near as I can estimate; I should say about 4½ tons.

553. Then 2,000,000 gallons of sewage affords about 4½ tons of precipitate?—Yes; it is not less than that. It is very probably a little over it. It is dry precipitate, when it is reduced to the dry form.

554. When giving me £5000 as the cost, was that with credit for the sales or without credit?—It was without credit for the sales. I have not entered upon that. There is a sale for the material, and it has been sold, but, as with all new articles in the market, it requires a little time to make its way. I may further say, that what the General Sewage and Manure Company have done at Coventry they are now quite prepared to do elsewhere.

555. How long is it since the company was formed?—It was formed in 1872. *John Charles Melliss.*

556. Then there would be no account of it taken by the Rivers' Pollution Commission, which sat some time ago?—I think not. I may here mention that the operations of the company have been kept tolerably in the background, for this reason, which I hope you will agree with, that they adopted what I think was a very wise policy. They said: 'There has been so much theorizing about sewage, and so much talk, misleading the public, that we will not come forward publicly with our scheme until we have dealt with the whole sewage of a town for a time to the entire satisfaction of all concerned, and then put the facts before the public.'

557. When were your works completed at Coventry?—They were completed and put in operation in April 1874.

558. And have you since April 1874 been dealing with the whole sewage of Coventry?—Yes. I may say, further, that I have been only a very short time in Glasgow; I only arrived this morning; but since I have been here, I have endeavoured to make myself acquainted with some of the local circumstances; and although it may seem presumption in me to say anything after having been here for so short a time, I think I have found out a little about the sewage of this place; and I believe, from what I can understand, that it is quite possible to deal with it by precipitation, just as is done at Coventry, without pumping. I have a great objection to pumping. Pumping sewage is a ruinous undertaking, particularly in faulty sewers where water gets in. Of course it is a very approximate thing, but I feel perfectly authorized in saying that the General Sewage and Manure Company are quite prepared to deal with the whole of the sewage of Glasgow in the same way as they have done at Coventry; and they will erect their own works, on payment of, I should say, a maximum rate of 1s. in the £ on the rateable value, or a minimum of 6d. Having been here so very short a time, it is very difficult for me to say anything which would be more definite,—so much depends upon the quality of the sewage, and a great many local circumstances,—but I am sure that I am stating a maximum and a minimum amount in stating what I have done. I am satisfied, from information which has been kindly given to me this morning by several gentlemen in the city, that very little, if any, pumping would be necessary, and that the intercepting sewers might be laid down and the sewage taken to a particular spot, where it could be worked by gravitation. The fall required for working our process at Coventry is very small. We do not pump there, we work it by gravitation. I have found from experience that pumping sewage with defective sewers is very expensive work, and very likely to land in a great deal of trouble. I may further add that there is no nuisance arising from our works at all. We have worked them now through winter and summer, at different temperatures, high and low; the men are all healthy, and like the work; and the works do not bear the aspect of anything objectionable in the slightest degree. In fact, I have made it a rule in throwing all my influence into this sewage question—which, I think, is about one of the most important that we have now to consider—to see that everything should be done in a proper, orderly, and cleanly manner, and that neither the men nor anything else about it should be slovenly. Hitherto we have been in the habit of saying, with regard to sewage, 'Oh, this is an objectionable thing; let us put it out of sight,' and in order to put it out of sight we put it into our rivers, and now we are suffering.

559. I think I have got all the information I want, and if I should want anything more I shall get it at your offices.—If you were disposed to inspect our works personally, in order to verify what I have stated, I should be most happy to show them to you.

William Millar.

Mr. Wm. Millar, Treasurer of the City of Glasgow, examined.

560. I would state in the first place, that of all the many systems that have hitherto been proposed for Glasgow, it does not seem to me that any one of them meets the whole requirements of the case in a satisfactory manner; these requirements are so various, according to the different districts of the city. Of course we have all considered the great scheme of Messrs. Bateman & Bazalgette, but I have certain objections to that scheme, which, with your permission, I would state. The first objection is to the enormous expense of pumping the whole of the sewage of Glasgow, including the rainfall. Were it only the sewage that was to be pumped, it might possibly be a manageable quantity, but the rainfall would involve an enormous amount of outlay.

561. Do you think they propose to deal with the whole of that?—The whole of it, including the rainfall. There is no separate system for the sewage; the rainfall goes into our sewers, and therefore the whole must be pumped, the same as in London. Now the quantity of rainfall will be vastly greater than the sewage water, —great though it is,—and would become so enormous as to be enormously expensive. Then that expense would require to be borne, in the first place, entirely by an assessment; and I should say that that assessment, if laid on over the whole city, would be altogether unfair to certain districts of the city. There are some portions of the city of Glasgow, as you are no doubt aware, that are actually benefiting us by their excreta. Were it not for the excreta of the lower parts of the city—that is, the middle and east parts—we could not dispose of our ashes at all; but in consequence of the ashes being mixed with that excreta, we are enabled to get a large sum annually out of our refuse. Therefore it would be altogether unfair to tax those people who are benefiting the city, in order to pay the expense connected with the great water-closet system, which is really the chief cause of the evil that is created. Then another objection I would have to Messrs. Bateman & Bazalgette's system is, that it would encourage the use of water-closets. Now I think our aim should be rather to discourage than to encourage the use of water-closets, because one great and necessary evil of these closets is the pollution of the sewers; and the gases arising from these sewers get into the houses and are injurious to health. I think no one can doubt that, to a greater or less degree, the gases from our sewers injure the health of the population, and that therefore the more water-closets are used the greater is the injury done in that way. My opinion would be, that, were such a system adopted, a tax should be put on water-closets specially, as being the great cause of the nuisance. Then I would also say, as being an opinion which I have formed, that no scheme whatever will be sound in principle that does not secure the utilization of the sewage, or rather the excreta, for the purposes of cultivation. It is intended by nature for that purpose; and if it is diverted from that purpose, it must come back upon us in some way or other, either in a deficiency of supply or in a difficulty of disposing of it. Now I should like to say, that if a scheme of drainage is to be adopted at all, such a scheme as Mr. Carrick's seems to me to be the most useful one for a large district of Glasgow. The district to the north-west of Glasgow is certainly the greatest one for water-closets. There is by far the greatest number of water-closets in it, and Mr. Carrick's scheme takes in the whole of that district. He would carry away the sewage by gravitation, without any pumping, to a district of country to the west of Glasgow which is admirably adapted for the purpose of irrigation. There is a large extent of level ground about Yoker which is admirably adapted for that purpose. Then, as in my opinion no one scheme would be applicable or fair in its application to all the districts of Glasgow, I would say that the city should be divided into districts for this purpose, and that each district should be dealt with in a different manner, and according to the circumstances of the district. I think that for that purpose a local board should be formed in Glasgow, consisting, I should say, of the Master of Works, two members of the Health Committee, the medical officer, and three members of the Trades House, or in any other manner that might be considered desirable; and to that board should be committed the duty of deciding as to the best means of dealing with each district of the city with regard to the disposal of its excreta or sewage, and that board should have power to compel landlords to carry out any arrangements that they may consider necessary in each district, and also to assess the inhabitants of each district, if an expensive system of drainage were considered necessary. I have taken no notice of the question of public works, which is of course a very important one in such a city as Glasgow, because I think that the Bill which is at present before Parliament on the pollution of rivers, if it is passed, would be sufficient to remedy the evils arising from public works in Glasgow; but as a matter of principle, I should say that every manufacturer should be compelled to purify the water that he uses before he passes it into any sewer or any river. Then, again, I have taken no notice of the outlying districts of Glasgow. I have only taken notice of the city itself and its suburbs; but I have really no opinion as to these outlying districts, or as to how they should be dealt with, except to this extent, that they as well as Glasgow, and to the extent to which Glasgow is compelled to keep impurities out of the river, should also be compelled to do the same thing. With regard to the various schemes that have been propounded, I don't want to say almost anything. I think I have seen nearly the whole of them in operation; but it seems to me that of the whole, these two, the charcoal dry-closets on the one hand, and the Liernur system of removing excreta on the other, are the best adapted for the requirements of such a city as Glasgow.

Mr. Gavin Chapman, Manufacturing Chemist, Glasgow, examined.

562. I understand you had charge at one time of removing the urine from some of the urinals in Glasgow?—Yes.

563. Are you still doing that?—Yes.

564. And you are well acquainted, I suppose, with Glasgow?—Yes; I am very well acquainted with it. I have, for the sake of conciseness, committed to writing a few remarks which I wish to make:—

'The sewage question in Glasgow has been for some years discussed from many points of view, so many, indeed, as to introduce no little confusion of ideas in regard to the whole question. It has been considered in its relation to the health of the city as affected by sewer gases; in its commercial aspects, as to the prospect of its being a source of profit, or the cause of great expense; and lastly, the question seems to have come forward most prominently of all, What is to be done to improve the state of the river? I presume that this inquiry has reference principally to the last question. Limited to this as the sole or, at least, principal end in view, the solution of the Glasgow sewage question becomes comparatively simple, as a great many proposed schemes of operation must at once be laid aside—schemes which, even if successful, would be very partial in their effect in the purification of the river.

'It is quite evident that there are only three general methods by which all schemes having the preservation of the purity of the river for their end must proceed.

'Either all polluting matter must be carefully kept out of the sewers, or, if allowed to get in, the produce of the sewers must be collected and purified before it flows into the river, or finally, without attempting any purification, it must be raised up by pumping, and made to discharge itself on some convenient part of the coast.

'In regard to the first of these methods, all experience shows it to be impracticable. It might be possible, by stringent regulations rigidly enforced, to compel all kinds of manufactories and chemical works to purify their refuse liquors ere passing into the sewers. It would be a very great hardship to some parties, in many cases an injustice, as well as an injury to the commercial interests of the city. It could be done, however; but after all, the most serious and most unmanageable source of evil would still have to be dealt with. Beyond all question, the ordinary excreta of cities is that which most of all pollutes rivers, and it is the very kind of matter which can only partially be prevented from getting into the sewers. It might naturally be supposed that, were a city completely furnished with water-closets and conveniences of every kind, the contents could be collected, and the sewers kept free from contamination. Experience shows it not to be so easy a matter. As a proof of this, I can offer the following data:—About three years ago the Health Committee of the city fitted up some water-closets with the late Mr. Hoey's contrivance for limiting the supply of water. The contents of these closets have been regularly collected, and I am in a position to state what is their average quantity and quality. In Abercorn Street, New City Road, there are, in a tenement belonging to Mr. Elder, seven closets in seven different houses occupied in all by sixteen grown-up persons and eleven children. The weekly produce is about 110 gallons, and the quality is about 180 grains of nitrogen per gallon. Now there are about 50,000 water-closets in the city; and supposing them to yield at the same rate, this would only give in all somewhere about 450 tons of nitrogen. In a city numbering about 500,000 inhabitants, the yearly production of nitrogen is at a low average, 10 lbs. per individual, or in all about 2200 tons; showing that, in the present state of things, the whole water-closets of the city, if trapped, and the contents collected, would not account for much more than about the fifth part of the whole polluting matter of the sewage; and the rest would inevitably find its way to the river by the sewers.' [I may say on this matter that I differ entirely from Treasurer Millar in his statement that the water-closets are the entire source of the contamination of the river. I think that is an entire mistake. In Manchester, for instance, where there are almost no closets, the sewage is just as bad as in cities which are full of water-closets; and this is a proof of it, that in Glasgow, at the present time, the water-closets are not supplying much more than one-fifth part of the matter that pollutes the river. It flows into the river in all different sorts of ways. These are actual data, which I am prepared to verify at any time, and which any person can verify, because the contents are drawn from these water-closets every week, and they are taken to a place, I think, in Stirling Road, so that the thing is quite a measurable thing; it is not a matter of guess at all.] 'Something of the kind must account for the fact that in cities where there are no water-closets, such as Manchester, the sewage is just about as filthy as in those where there are.

'There is no doubt that by a perfect and thoroughly organized system, extending to the poorest and dirtiest parts of the city, this state of things could be improved, and a very much larger part of the total excreta kept out of the sewers; but I cannot conceive of a state of things so perfect that there would not be a large margin finding its way uncontrolled to the river. And then, in a large and rapidly increasing city, the margin would become an absolutely larger one year by year, whilst the river remaining always the same would, in the process of years, gradually become as polluted as ever. This objection must therefore apply to all schemes which profess to collect and deal with this part of the sewage by itself.

'With regard to the plans proposing to deal with the total sewage in a body before entering the river, the most of them proceed on a totally mistaken idea that sewage can be cleansed by screening, filtering, and keeping suspended matter out of it. A certain benefit no doubt could be derived from the absence of solid matter at the bottom of the river, but it would be a very partial one, and not worth the labour and expense that would require to be expended in accomplishing it.

'Almost the same kind of remark applies to the different chemical processes which have been proposed to deal with the sewage in bulk. It has to be borne in mind that, owing to the large consumpt of water, the sewage of Glasgow is less than half the strength of that of London and many other large cities. Processes, such as that of precipitation by sulphate of alumina, perchloride of iron, and that known as the A B C process, would only result in a waste of the chemicals employed, and produce no good result.' [I noticed that a gentleman who preceded me, Mr. Melliss, mentioned, if I heard the figures right, that the effluent water flowing from the sewage, after it is cleansed, contained rather more than a grain of ammonia per imperial gallon,—being four of one and six of another. [*Mr. Melliss.*—The figures in the analysis are ·630 grains of pure (saline) ammonia, and ·042 of organic (albuminoid) ammonia.] Well, that is almost three-fourths of a grain per gallon, including the saline ammonia, and that would be almost one-third part of the whole organic matter in the sewage. Now the sewage is very weak; it has not much more than two grains per gallon on the average; and if you take that as diluted with the rainfall, it would be much weaker. I am, however, taking it without the rainfall at all, so that, even with such a process as that, you would still have nearly all your polluting matter left in it when it flowed into the river. It is so very weak that it makes it almost a hopeless matter to deal with it by any process.] 'Perhaps the best plan of the kind, and the one best adapted for a very weak sewage like that of Glasgow, would be precipitation by lime. This would certainly throw down all suspended matter in the sewage, make a clear liquor, and rid it of all offensive smells, except that of ammonia; but this would require a very heavy outlay at the first, to put up the necessary works, and it would entail a constant expense afterwards, because experience has shown that, though the resultant manure has a real value, it is practically unsaleable.' [These manures are just of the kind which Mr. Melliss described. In Leicester, for instance, they had a manure which was of the theoretical value of 20s. per ton, but in reality they could get almost nothing for it. In fact, when I was there, the farmers were welcome to come and take it away for nothing.

565. You are now speaking of that which was simply dealt with by lime precipitation?—Yes.

566. I know that in Leicester it was practically of no value.—That is the case. The sulphate of alumina throws down a little more of the nitrogenous matter, and makes it a little more valuable, but, of course, it only throws down a portion of it.]

'The only other method of dealing with the sewage in a body that can claim consideration is irrigation. Here we are met, however, with all kinds of difficulties. The weakness of the sewage, the abundance of the rainfall in the West of Scotland, and the great improbability that the inhabitants of any large district of the country would allow it to be turned into a great sewage farm, are insuperable objections to any prospect of good being done by irrigation. It could be tried on a small scale, but, looking at the little success that has attended it in other places, and especially at the peculiar difficulties which surround the subject in the case of Glasgow, it would be mere folly to suppose that any return could be got by irrigation in the way of lessening the expense of removing the sewage. There may be many ways yet discovered of removing part of the value which undoubtedly exists in the sewage, and it would be unwise to neglect them; but if the river is to be thoroughly and properly cleansed, it must be paid for in the meantime.

'To get the river pure and limpid would be a kind of luxury. In its present state it is not so bad as that of many of the rivers in England. Things might go on as they are for fifty years, and it would not be so bad as the Irwell in Manchester and the Aire in Leeds are at the present time. There is no proof that, in an im-

Gavin Chapman.

proved state, it would do anything to improve the sanitary state of the city; but it would be certainly a great boon to be able to look down on it from the bridges and see it bright and clear, and to be able to sail down it without being annoyed by the stench, which is so offensive at present. It is the question of 8d. to 10d. on the rates.' I think 1s. on the rates, which was what Mr. Melliss spoke of, would be something enormous. [*Mr. Melliss.*—I said from 6d. to 1s.] Well, to pay a company from 6d. to 1s. for taking the matter out of the sewage by a chemical process, when it could be taken to the sea for 10d., would be great folly. The question just is, Are the public willing to pay for it?

567. I think you gave the quantity which would be taken and disposed of by the present number of water-closets as one-fifth?—Practically, it would be about one-fifth.

568. I don't know if you gave the quantity which you think would be disposed of if every tenement had a water-closet?—No; but I don't think that one-half of the city is supplied with water-closets just now.

569. Then, suppose the entire city had water-closets, how much of what you call the sewage of the city would find its way into the river?—I should say somewhere about one-half.

570. I see it is stated in one of the tables which have been put in that there are now 31,000 water-closets and about 100,000 houses in the city, so that that would only be about one-third?—Yes; but I was going on the assumption that there were 50,000. I have heard the number variously stated.

571. With reference to precipitation by lime, have you had any experience of it?—Yes.

572. I ask you the question because I was informed at Leicester that the effluent fluid, with precipitation by lime, although it comes out without smell and quite clear, yet in a few days begins to smell again almost as bad as ever.—It has a smell of ammonia. The system at Leicester is very far from being a good one. It is too hurriedly done. The tanks are by far too small, and the sewage does not get time to settle. It is run away into the river before the precipitation is complete.

573. I saw the operation there. The water came out from the building without smell, and quite clear; but the burgh surveyor assured me that by the time it flowed three or four miles down the river it began to smell again.—That is the case. It is not perfectly cleansed. There is no doubt it is a great improvement, and the water is quite clear, but it is not perfectly cleansed. There are none of these chemical processes that have succeeded in making the water perfectly clean.

574. I have been furnished with the result of an experiment by Mr. Coleman of using crushed shale as a filter, a process which I think is deserving of further experiments. This bottle (showing) contains sewage, while the other bottle (showing) contains the result after the sewage had been passed through a layer of 3 or 4 inches of crushed shale. Mr. Coleman said he was very much surprised at the result himself, for the water came out as you now see it; and although it has been kept in his office for a considerable time, it has still no smell. It would seem to me from that experiment that that material might be very valuable as a filter, assuming that these samples are a fair test of it, because crushed shale is a very cheap material, and there would be plenty of it. Has that been tested in any way chemically?—[*Mr. Carrick.*—No. Mr Coleman got the sewage from me, and he sent me that as the result of his experiment.]—Sewage is a very deceptive thing to look at. The smell is certainly away from that sample, but it would be necessary to test it chemically. The Glasgow sewage is so very weak compared with the sewage of other towns, there being not above two grains of nitrogen per gallon in it, that any chemical process has little effect upon it. Many of the processes that are practised upon the sewage of English towns take a good deal of matter out of that sewage; but even after that, it is not much better than the Glasgow sewage is at its worst. We are drowned here with water altogether.

575. One of the great objections to the precipitation by lime, and what apparently they were suffering from at Leicester, was the accumulation of the precipitated matter, which they could not dispose of at all.—Yes; that is a great source of trouble.

576. They could not sell it, and they could not even get it carted away for nothing.—Quite true; and it remains there accumulating, an enormous nuisance to the place. It is manure, however, if it could be got taken away; but if it stands any time in bulk, the ammonia must go away from it. If it was fixed by an acid when it was coming out, then it would be all very well; but that cannot very well be done. It is lime, and no acid will fix it until you neutralize the lime; and it would take an enormous amount of acid to do so.

577. Have you any experience as to the nature of the street refuse—I mean, as to the quantity of organic matter it contains as compared with sewage?—I see it taken off the streets and carted away continually; but all that I know is, that it is a very unequal thing. Sometimes it will be a great deal better than at others. Of course there is a good deal of it that consists of the droppings of horses, and the abrasions of the granite, and so on; but it is just mixed up along with the ashes and the refuse from the works, where there are a great many pans and pan-closets.

578. Can you tell me anything about the matter from the back courts? I went into a few of them yesterday, and, from what I saw, I should think the washings from these back courts would be nearly as bad as sewage—the courts were so dirty. If a shower of rain was coming on, and washing that out into the sewer, I should have some difficulty in judging which was worst.—These back courts must have been some unfavourable specimens, for Glasgow closes are pretty well washed out now.

579. I know that the smell was very bad, and the filth was very considerable.—They are vastly improved now from what they were.

Mr. J. C. Melliss, recalled.

580. With regard to the works at Coventry, I think I omitted to mention that that is really the only instance in the kingdom at present where the whole of the sewage of a town is dealt with to the satisfaction of the authorities.

581. I quite understand that you deal there with the whole of the sewage?—Yes; and that has been extending over twelve months to their satisfaction.

582. And you don't require any separate system previous to treating it?—No. We have got beyond mere laboratory experiments; and adopting the system and trying it for twelve months has done the whole thing. With regard to the manure produced, I may mention that our manure is of a better quality than that produced by a precipitation of lime alone; because we don't allow any solid matter to go into the sewage with our chemical.

583. I am not assuming for a moment that the precipitate which you get at your works is of the quality of that which I saw at Leicester.—No; and of course we have sold it, and we are selling it at the price I have mentioned.

Mr. John Purvis, 222 Buchanan Street, Glasgow, examined.

584. I am a hotel-keeper at present, but I have been an agriculturist during most of my life. I am only an eight years' residenter in Glasgow, but I have looked about a good deal with regard to this great question; and I think, from the lie of the river and the sluggish state of its current, that it is an extraordinary thing that such a vast amount of stuff should be allowed to be poured into it. I think that to propose to run it away

to a great distance, and use it for irrigation in some country place, or to run it away into the sea, is out of the question; because if it were run into some country place, it would ultimately become a nuisance and would be condemned, while conveying it to the sea would be such an enormous expense, and put a stop to a great many other things while it was going on. There is a plan which I have thought of many a time for meeting the difficulty, and that is with regard to the water-closets. To deal with the water-closets in the way that some people speak of would make such a war among the tenants that I don't think it possible to get it done. My plan would involve very little alteration on the water-closets at all. I would leave it to some tradesman to make a sufficient closet, or pan, or whatever it may be called, with a sufficient close lid; then the streets should be laid out, and the connections with the houses made, somewhat in the same way as they are made by the gas people. The parties would then know the places where they begin and where they end. After the connections once get set a-going, they would know the time at which to come for my closet, and they would just come to my house, and, without any annoyance whatever, they would put in the clean pan or closet, and take away the foul one. Then there would require to be one or two manure-works outside the city, where the stuff from the closets would be manufactured into a very valuable manure. Some people say that that manure would be of little value; but the cost would be so enormous in running away the sewage in sewers or otherwise, that I think the mode I have proposed of collecting it from the closet would be the best way of doing; and I know that the manure would sell. I have been a buyer of manure for the last twenty-five years, and I am certain the price would run from £8, 10s. to £10 per ton, and the process would leave a profit in the end.

585. Then you propose a kind of moveable cesspool, in fact,—some vessel or other in each house,—and that the matter from the closets should go into that vessel, which would be lifted out and carried away, while a clean one would be put in its place?—Yes. There is one thing I forgot to say, and that is, that I would abolish all water in the water-closets. I would have a urinal for males, but no water to go into the closet, as that would destroy the system. *John Purvis.*

586. How would you get the matter to run into that vessel?—The vessel would be lifted out bodily from the closet. Some people say there would be a stench from it, but a little hopper could be put on the top, as in the dry water-closet, which would not cause much expense, and then there might be a bell-handle, which would bring down a little of the charcoal and deprive the matter of its odour.

587. Then you would do away with the water and use charcoal?—Yes. The idea of attempting, in this great city, to make sewers which would convey the sewage to the sea, which would be attended with such enormous expense, is quite out of the question; and even when it was done, I question very much how it would work. There is no doubt at all that the excreta of towns is a very valuable manure, and it is a very extraordinary thing, at this time of day, that it should be lost in any town. As the city is increasing very fast, this plan of mine might be tried in one district to see how it would work; and one manufactory might be tried in the outside in the meantime. There is no question whatever that it is the closets that are the great source of the pollution of the river.

588. Don't you think that if your plan were adopted, a great many people would object to a man coming into their houses once a day to carry off this pan?—No. If the thing were once set a-going, I see no inconvenience there would be. It would be the very same as the gas man coming in, without law or leave, as I may say, and taking a note of the gas.

589. I should have a decided objection to the gas man coming into my house every day.—But it would not be every day. I should think it would only be somewhere about twice a week.

LONDON, MONDAY, 27*th December* 1875.

Present:

SIR JOHN HAWKSHAW.

SIR JOSEPH WILLIAM BAZALGETTE, C.B., Engineer of the Metropolitan Board of Works, examined.

590. *Sir John Hawkshaw.*—I think you had some experiments made at Crossness with the A B C process?—The A B C Sewage Company applied to the Metropolitan Board of Works for permission to erect their works at the Board's outfall at Crossness, in order that they might there try the process of purifying the sewage, and that the Board might have an opportunity of watching that process during the experiments, and coming to a conclusion whether they thought it would answer to be used by them or not. At the end of the period of that experiment, I made a report to the Metropolitan Board of Works upon the result some few years since,—the date I do not at this moment remember, and the details I do not at this moment remember,—but the report is printed, and I should be very happy to place in your hands a copy of that report, which will give the details in a way that I cannot do now. But I can state generally the result, which was, that after very considerable expenditure in works and in manipulation, the Company did obtain a considerable amount of purity in the effluent water, and that that was done without creating a nuisance, except so far as sewage works at all times are objectionable; but it was done at considerable loss, about £6, 6s. per ton. The Company claimed to have sold some of the sewage deposited for a considerable sum; but upon investigation it turned out that those sales were not *bona fide* sales to the public, and that there really was no market for the residue—in fact, that the process was so costly that it was not one which could be continued at Crossness, and the result was that the Company were called upon to take up their works, and the whole thing has been removed. Of course the Metropolitan Board of Works felt that any process for purifying sewage and dealing with sewage, or any proposal for doing it, should have a fair trial. There was great difficulty about it, and they were anxious to obtain all the information upon the subject that they could, particularly when a Company undertook to do it at their own cost. *Sir Joseph William Bazalgette.*

591. Is there any other process of which you are aware, which, in your opinion, would be more likely to prove successful?—No. In my opinion every plan of disposing of sewage by means of precipitation, or abstracting the solid from the liquid, has failed. At Birmingham at the present time, as you are aware, they are carrying out large works for dealing with the sewage by the lime process, under Mr. Hawksley. The works are very well devised, and at Birmingham it is the best thing that they can do at the present time; but they are such works as could not be carried on in the neighbourhood of any town or city without creating a nuisance to the neighbourhood where they are erected, and being highly objectionable. They are not remunerative, and they cannot deal with the sewage in times of heavy rain. In fact, I went down to those works, I think last year, to look at the property of Sir Charles Adderley, which had been flooded in times of rain; and the ground was covered with sewage, the walks in his garden

Sir Joseph William Bazalgette.

included; and I think that the Birmingham Corporation have since paid a very large sum in compensation for the damage done to his property, in spite of those works. I think I may go so far as to say that they regard those works as temporary works till some better plan can be devised.

592. Is the plan the same, so far as you know, as that which has been adopted at Leicester—the lime process?—Yes. The lime process adopted at Leicester was the first idea of separating the solid from the liquid, and then, as you know, it failed, principally on account of the immense amount of deposit; and that is the great difficulty with the lime process,—the more lime you put in the more deposit you get, therefore on the one hand you are spending money in providing the purifier, and you are increasing the quantity of deposit to be removed and the cost of removing it, so that it will not pay. Mr. Hawksley has suggested many improvements in the mode of manipulating the sewage since it was tried at Leicester; but it is remarkable that after twenty-five or thirty years' trial so little progress has been made with this process. The truth is, that with all those experiments,—the mere laboratory experiments upon the table, which appear a perfect success,—they will produce to you clear water passing off, but the very moment you come to try it upon a large scale in a town, it is a failure, and it is a failure for the reasons I have given: first of all, that the precipitant is very costly; and then, that it increases the difficulty by increasing the deposit, and therefore there is always a tendency to shirk carrying it out properly. They shirk carrying it out at night, they do not put the full quantity in, and they try to save in every way, and are directly interested in saving. At Cheltenham they tried the same process, and after a considerable amount of litigation it failed; and I think now they have recourse there to irrigation. At Weston-super-Mare they tried it for some time, but it led to much litigation by reason of its creating a nuisance, and it was abandoned, and we carried out an intercepting sewer, discharging into the sea at a distant point, and they have had no complaints since that time.

593. Do you know anything about their proceedings at Leeds?—No, I do not.

594. They have, I think, adopted the same process—the Native Guano Company's process?—Yes; but I do not think that any of those, the Phosphate Sewage, or the Native Guano, or the A B C, is an improvement upon the lime process, which was the original one.

595. When I was at Leicester, Mr. Hawksley and I went together to the borough surveyor, and he told us that their difficulty was in dealing with this residue, that he could not get the farmers to cart it away.—Precisely so. There are inland towns so situated that you must have recourse to some process or other for purifying the sewage; and in that case any one of those processes you may fall back upon, in order to get a certain amount of purity. You may be obliged to do it, but you can only do it at very great cost, and you can only gain partial success. In the same way you may have to revert to any other process. They have tried the earth system in some situations with considerable success; but in large towns you must get rid of the surface water,—you must get rid of the washings from the houses,—and you must therefore have sewers.

596. Do you know at all what is likely to be done or proposed to be done in the upper part of the Thames? I think I saw some suggestion of your own lately in one of the papers?—Yes. You may take the Thames as an illustration of what I have just been saying. All the towns in the Thames valley drain more or less directly into the Thames; and the Thames Conservators have served them with notice to divert their sewage from the river, the Thames being the source of water supply to London. They have tried all kinds of plans,—sewage farms, and deodorizing processes, and every suggestion that can be made,—and they have one after another failed.

597. Is there anything now at all in contemplation with regard to that subject?—Yes; there is at this moment an inquiry being held by Colonel Ponsonby Cox. I have laid before him a proposal which has been before the public for some few years, that those towns in the Thames valley should combine, because it is impossible for them single-handed to construct outfall sewers which shall carry the sewage sufficiently far away from the neighbourhood, and it is a locality unsuited altogether for sewage farms. And last year I made the same proposal for West Kent, that they should combine and construct an outfall sewer, and carry the sewage into the river Thames, at a point some seven miles below the Barking outfalls. An Act was obtained last year for the construction of an intercepting sewer, which is to take the sewage and form an outfall for the towns of Dartford, Crayford, all the Crays, the Cray valley, Bexley, Bromley, Beckenham, and other places. That sewer is carried about thirteen miles in the country, up near to Croydon, and it now offers an outfall, if enlarged, for the whole of the sewage of the Thames valley; and therefore what I have proposed is that those towns in the Thames valley should unite, and have a representative body of a certain number, who should take charge of the main outfall works, and construct sewers discharging into the West Kent authorized sewer, by which means the whole of the sewage of the Thames valley will be removed, and carried to the river at Long Reach.

598. Is the point of outfall Long Reach?—Yes, in Long Reach. The great difficulty to be contended with there is the difficulty of getting the different towns to unite. Some approve and some object. There will always be a difficulty where it is necessary for a number of towns to unite to carry out one common object; but where several towns are situated close to each other, there is a very great advantage gained by their combining. I will put it in this way: Assuming one town requiring a sewer of one foot in diameter and nine towns of the same size were to unite, and put in a sewer three feet in diameter, the excavation for a sewer three feet in diameter is the same as the excavation for a sewer one foot in diameter. And the discharging capacity of a three-foot sewer is more than nine times the discharging capacity of a one-foot sewer. Again, the velocity of the current is greater where there is a large body of water passing through a large sewer, and therefore less fall is required—and less fall means less pumping. Then the pumping is not to be measured by the actual power. If divided into a number of different pumping stations, it is greatly increased by the wages paid to the different people at them. If you can unite the whole into one pumping station, a small staff working large engines will do the work of eight or nine small pumping stations. So that in every point of view there is great economy in uniting; and I think that may be applied to Glasgow. There are towns near to Glasgow which contribute sewage to the Clyde which would be very advantageously united to that city in disposing of it, who would be certainly unable to do it advantageously by themselves.

599. Can you tell me what is the cost for pumping sewage under the Metropolitan Board of Works?—I cannot. I do not remember the figures at this moment.

600. Do you have duplicate engines at the stations?—Yes, we do. We provide for taking the maximum flow of sewage, and have duplicate engines to cover the increased quantity of rainfall, and so on. I think in many instances great economy would be effected by having an equalizing reservoir, so that when a great flow of sewage came in, there is a reservoir to receive it, and let the pumps take it off more gradually.

601. And to distribute the duty over a longer period of time?—Yes; that in some cases may be very advantageously done.

602. What description of pumps do you generally use?—Double-acting beam engines.

603. Vertical cylinders?—Plunger pumps.

604. Have you never tried the centrifugal pumps?—No; they do very well with a small lift. We find ours have acted remarkably well.

605. Could you give us any information about irrigation in cases that you are aware of? You say it is applied at Croydon; the accounts that one hears of it are rather conflicting. Some say it is no nuisance whatever putting sewage into the soil?—I do not think it is a nuisance at Beddington. A sewage farm is a thing which I should not like to have near my residence; there is some smell from it at times. But I do not think it may be said to be a nuisance at Croydon, for there are persons who are building wonderfully near to the sewage farm; but, at the same time, I think it would depreciate the value of residential property to have a sewage farm near it.

606. Would not it be rather dependent upon the size of the farm, because a small farm might not be so great a nuisance as a larger?—I do not think so. I think it would depend upon the quantity of sewage put upon it, and the way in which the farm is managed. At Croydon, the Corporation obtained land, I think, at a rental of £10 an acre, and they let it with the sewage upon it to a Mr. Marriage, a Quaker, at a low rental, so that he worked it for some time at a profit: the Corporation were sustaining a loss. Mr. Marriage afterwards gave up the farm, and the Corporation are now working it at a considerable loss. There is no doubt that by irrigation sewage may be thoroughly purified.

607. You mean, I presume, the effluent water?—Yes; the effluent water may become quite purified; but it is only under very exceptionally favourable circumstances that that can be done at a profit. If there is a heavy rent to be paid for land, or if there is pumping to be paid for to any extent, that would reduce the return.

608. I remember visiting the Barking Sewage Farm on one occasion, and dining with Mr. Hope, who had the manor house, which is pretty near the farm, and certainly the smell in his dining-room was something fearful on that occasion, which was in July?—Certainly there is a smell when you are putting the sewage on the land, and if you walk over the land you perceive the smell of sewage; but, at the same time, you may be very near to the farm and not perceive it; and, as I tell you, there are a number of very good villas which have been built very close upon the margin of the Croydon Sewage Farm.

609. That farm is of very small size, I take it?—Not very small. I should say that there are two great difficulties in dealing with sewage: one is the bulk of the water which carries it down, and the other is the great quantity of land concerned in purifying it.

610. Have you ever made yourself acquainted with what is called Liernur's system?—Yes. I have looked into it; it is what is termed a pneumatic system. He lays in iron pipes connected with the different closets, and he has a reservoir in the streets; and he has an air-pump, and he creates a vacuum in the pipes, and draws all the sewage down from the house into the reservoir in the streets; and he says that the vacuum being always kept up, there can be no escape of air into the houses. He also says that he can use it, and that it is not necessary to do away with the water-closets—that he can use it with moderate supply of water; but it must be a very moderate supply, and it must be an exceedingly costly process. You must have in addition to that a sewer for carrying off the rainfall and the washings from the houses, which putrify and are very offensive; and you must have these iron pipes laid down; and you must have pneumatic pumps to pump the offal out of the houses into the streets; and then you have iron pumps, again, to pump this through iron mains out of the streets, or you must have carts to go round and take it away. In fact, altogether it is so complicated a business, and so expensive, that it will never answer. Of course, the iron pipes to begin with are much greater than the cost of laying down other pipes. Then there is another process which is very much in favour at this moment, because it helps to get rid of what I may call the land difficulty; and that is the intermittent downward filtration system, which Mr. Bailey Denton has started at Merthyr Tydvil, based upon the experiments of Dr. Frankland, who showed by experiments which he made that the sewage from 3000 people could be filtered through an acre of land drained 2 yards deep so as to purify it entirely. Based upon that theory, Mr. Bailey Denton laid out a farm at Merthyr Tydvil, and he drained it 2 yards deep, and poured the sewage for a short time of 1000 people per acre upon that land; and then, based upon that experiment, it is proposed that all over the country where there is a difficulty about obtaining sufficient land for sewage farms, to fall back upon intermittent downward filtration, and to put the sewage of 1500 or 2000 people to an acre of land, regardless of the soil. That proposition rendered it necessary that I should go about two years ago to Merthyr Tydvil to see what was done, and there I found that there was a gravelly soil 50 feet in depth, an admirable opportunity of drainage, and circumstances more favourable than could be obtained almost in any other place, and that they did for about six months under those favourable conditions apply the sewage of 1000 people to the acre without causing any nuisance; but that the engineer who had charge of it, a very intelligent engineer of the name of Harper, came to the conclusion that even under those favourable conditions you could not apply the sewage of more than 500 people to an acre safely and permanently. The plan for this process which they adopt is to take three acres to begin with; they divide it into three, and they irrigate 1 acre for one year and leave the other 2 acres at rest. Next year they turn the sewage upon the second acre, leaving the acre which has been under sewage for the former year two years to purify itself again. Now that calculation means, that before the year was out for some time, and for some time after the year was out, the land has been charged very heavily with sewage, and therefore cannot have been in a proper state for purifying sewage. Then they divide the acre which is in use into three parts also, and they pour the sewage for eight hours upon one part, eight hours on another, and for the remaining eight hours upon the remaining third; therefore, if there are 1000 people to the acre, there is going on a portion of the land for a year the sewage of 3000 people—that is, 1000 people upon one-third of an acre, which is equal to 3000 per acre. The theory is, and it is a very good theory, that the sewage should be allowed to go through land well drained and well aerated, and coming in contact with the air it is oxydized and purified; but if it is allowed to be upon the land for any length of time, it gets clogged and the sewage is not purified, and therefore they apply it intermittently, and they allow it time for the air to pass through it. It is a very useful plan, as are all other modes of dealing with sewage under certain conditions; but it is very apt to be taken up, as most of those theories are, and applied too extensively, which must only end in great disaster. The fact is, that for a city of 500,000 inhabitants it should be very carefully applied only under very favourable conditions, and not carried to too great an extent.

611. It would take 1000 acres?—No doubt it would take 1000. 600 must always be at rest for two years whilst they are dosing the other third.

612. Do you know anything of Mr. Odams' cylinder for straining sewage?—Yes, I have seen his models.

613. It is hardly in working order; but Mr. Odams is making it, and he will let us know when it is ready. He proposes to make these cylinders of gauze as fine as a silk pocket handkerchief, and make them revolve rapidly, so that the liquid will escape by centrifugal force, and the solid parts be retained?—It is the same principle as Leatham has used for some time at Croydon. They strain it through wire gauze; only there it is an upright wheel which revolves, and as the sewage passes through it is deposited and falls into a groove, which is worked by a Jacob's ladder, and drains it away. And then he has continual jets of water, worked by the same power, which keep washing the gauze to prevent its being clogged. Mr. Odams thinks that the gauze in his cylinder will be kept clear

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by this continual revolution and throwing it off. I think that there is considerable doubt about that; and when he has done it he has only taken out the more solid portions, which are held in mechanical suspension. The ammonia, and all those portions of the sewage which are in chemical solution, are carried off with the sewage, and when decomposed will become most offensive; so that really that is only a very partial thing.

614. Supposing that it will do what he says he intends it to do, it would seem to be a process for taking out a portion of the solid matter of the sewage—that is all?—Yes. One is so accustomed to hear of the different processes which are brought before you being perfect successes, and to hear them even quoted, after they have been in operation for some time, as a perfect success, and to see them abandoned after all, that one looks upon them with caution. Scott's process was said to be a most admirable solution of the difficulty, and at Birmingham it is said to be in operation now; but if you go to Birmingham you see that they make about 4 tons of cement by Scott's process in the week, and it is a mere flea-bite compared with the bulk of the sewage that they are dealing with. It is a mere experiment; and besides, they do not get rid of the cement—they cannot sell it in bulk.

615. Do you know any case where those Companies are disposing of the residue of their manufacture to any advantage?—Not one.

616. Is there anything further that you would wish to say with regard to any of those processes?—My observations apply to all that I am aware of, and I think I have seen most of them; that is to say, that they are none of them succeeding commercially,—that they have been all had recourse to under circumstances of difficulty to help to purify, but that they can only succeed where there is no great bulk of sewage.

617. It is essential that these things should be proved to be commercially good, because in making an outfall sewer it is not a paying transaction, and therefore it may be necessary in some particular localities to have recourse to some of these processes, whether they are profitable or not, as the only means at hand?—Quite so. I may mention St. Leonards. At one time I recommended them to have a sewage farm at St. Leonards. There was land near St. Leonards which was available, and they said to me: 'In our houses at St. Leonards there are a number of invalids and persons who study their health, to whom a sewage farm would be frightful, and they would go away; and whatever the profits upon that farm might be, it never would compensate for what we should lose in our rents.' I felt that that was a very strong argument, and a very reasonable one.

618. What did they do at St. Leonards?—We carried the sewage into the sea very much in the same way as at Brighton, and it answers very well, and they are perfectly satisfied with it.

619. Do you find in your large receptacles at Crossness and Barking any large accumulation of deposit?—It all washes away. There is a scum forms upon the bottom, but it all washes away.

620. In fact you have not in reality ever to clean them out?—No.

621. Then they are so far self-acting?—Yes. I may say that at Bournemouth also it was proposed, I think, by one of the Government inspectors, to apply the plan that is being adopted at Birmingham. I mean the plan of using the lime process, and deodorizing the sewage; but the Bournemouth people felt very much as the St. Leonards people did,—that although such a process might be tolerated in the outskirts of Birmingham, or in a low neighbourhood, to adopt such a plan there would be ruinous to the reputation of the town. They have not carried out anything as yet; but they probably will carry out an intercepting sewer to some point into the sea, where it will cease to be a nuisance. At Birmingham they spread the deposit over a large tract of land, let it dry there, and then dig it in. They always have a portion of the land covered with this deposit in a wet state, a portion of it covered in a drier state, and a portion of it that they are digging in.

622. There must be an end, must there not, to that process some day?—Of course it takes up a great deal of land. The way that they tried to get rid of it was to crop that land and thereby to exhaust the manure; but they found that the dug part of the land at Birmingham was so rich, and so fed with sewage, that nothing would grow upon it. It was quite a nuisance. That was before they carried out their new works.

623. The attempt at Birmingham two or three years ago was to get a large sewage farm, and they applied to Parliament for an Act, but they failed?—Precisely so. One has been accustomed to hear Birmingham quoted for years as a great success in dealing with sewage by the lime process, and also afterwards as great success in dealing with it by Scott's process. Ealing, again, was quoted as a great success for disposing of sewage by Scott's process, but they have abandoned it there, so that really you cannot form an opinion of what the result will be for the first year or two.

624. I see that the date of the report by yourself and Mr. Bateman upon the sewage of Glasgow was 1868. At that time I do not know that you recommended, but you contemplated the possibility of sewage being largely applied to farming purposes?—Yes; we recommended that an independent outfall should be provided for the disposal of the sewage, and we then pointed out that there was land very suitable for irrigation—a sandy soil—in the neighbourhood of that outfall, upon which we thought it might be used with profit; but the scheme of our getting rid of the sewage was quite independent of the irrigation scheme. There can be no doubt that a sandy soil would be very much improved by irrigation of any kind, especially during the summer months.

625. Have your views as to the value of irrigation changed since then at all, or do they remain very much as they were?—I think as to profit I am less sanguine than I then was. In that report we quoted a good deal from the Barking farm. Now I understand that the Barking farm is being given up.

626. I understood a considerable time ago that it was not profitable, but I had not heard what had happened to it lately?—I cannot speak positively about that, but I believe that is so.

627. Of whom was the Barking farm held?—I do not know who the owner is.

628. Does Mr. Hope get your sewage?—Mr. Hope has nothing to do with the Barking farm. Mr. Hope is now utilizing the sewage of Romford.

629. I mean, whoever has that farm, does he get your sewage?—Yes, he gets our sewage. The term expires in a few months for which that Company have a lease of the sewage of the metropolis. I should explain that that Company was formed for reclaiming a portion of the Maplin Sands on the Essex coast, taking the whole sewage of the metropolis, and they commenced their work for that purpose.

630. Have they not proposed to the south side as well?—No, only the north side. They got a lease of the sewage for the north side, and in order to show what could be done by sewage irrigation at that time, and to enable them to raise the necessary capital for the larger scheme, they established near to Barking a small sewage farm; they carried a portion of the sewage on to that farm, and tried their experiments on it; that farm was the one which was referred to in the report by Mr. Bateman and myself in 1868. Mr. Bateman was at that time joint engineer with Mr. Hemans for carrying out the works of that sewage irrigation scheme. However, the capital was not raised, and the works were not completed. The lease is now expired, or is about to expire, and I believe the Barking sewage farm is about to be given up. No doubt that in the Craigentinny meadows, and in many other places, wonderful crops are produced under sewage irrigation; but still, there we have the fact that very few sewage farms for some reason or other are made to pay.

631. They produce very wonderful crops at the

Barking farm. I saw ten acres of strawberries there which were larger than walnuts; but I could not then get, though I tried to get, at the expense which they had been at to distribute the sewage, which is a very important element. I could see the conduits of iron. Of course the sewage will not flow on a flat surface. You must give it a fall; and I could see from the appliances on that farm that the expenditure per acre must have been very considerable; they either did not know it, or at all events they did not choose to tell me?—That has always been very difficult to get. You can see clearly that my view is that I should not rely upon a sewage farm as an outfall if I could obtain a more certain one, but I should endeavour to place my outfall near land suitable for the reception of sewage, to which in future time it might be applied if possible.

632. You mean if you could do it without reference to other interests?—Yes. I should think it is an advantage where it can be done. I am afraid we must regard sewage as an enemy to be got rid of, and not as a friend to be sought.

633. Supposing a sewage outfall farm were made, which, as you are aware, is a very expensive work, and a work which should last for all time, what would be your opinion as to carrying it over ground containing coal, which might be worked hereafter, and which, if not purchased, might lead to the deflection of the sewer?—I should endeavour to avoid such a position, of course.

634. A sewer is not like a railway; I have made hundreds of miles of railway over coal, but we can lift them up from time to time; but a sewer cannot be lifted up?—Precisely so. We say in our report, 'The conduit throughout its whole length will be upon the coal-measure formation, and by the position of the workable coal and minerals the line selected will fortunately escape all workings except for the last two miles, and be constructed upon ground not liable to be affected by mining operation.'

635. In making those two miles, does not it follow the workings which are now in progress?—We go on to say, 'The tunnel will be wholly in the "blaes" or sandstone; and a tunnel at so small a depth from the surface in these strata may be constructed nearly as cheaply as if it were made in the ordinary way of cut and cover.' Of course we had our attention called to it at the time.

636. I could not quite understand from the report, when you were speaking, I think, of being two miles in the coal workings, whether you meant present workings or prospective workings?—I do not remember. I should think, present workings.

637. I rather read the report as referring to present workings?—Probably so. We came to the conclusion that our line was pretty safe from any contingency of that kind, from the best information we had.

638. I could not quite gather from the report whether you were looking at workings that were already in existence, or workings which may be formed from time to time. One of the difficulties in dealing with this region is that there are portions in which future workings may be very serious indeed, so serious as to render it unadvisable to make any very costly work over ground of that sort. There are cases of that sort in the region of the Clyde, where the remaining coal which has yet to be wrought is so thick and extensive that to make a very costly work over such ground would lead to great risk of its being destroyed in the course of time; still, work of this kind must be made for future time?—Yes; that is the case.

639. There are some particular portions of it where the workings would be very extensive indeed, and ultimately would lead to a very great depression of the surface, not in this particular neighbourhood, but in other parts that I have had to look at where the ground may be very much undermined, which is a great difficulty in dealing with some of these questions?—Yes; it is a point which requires very careful consideration.

640. Will you explain the way in which you raise your money in the Metropolitan Board of Works?—We raise money by issuing bonds in the market, giving security for those bonds, and we raise them at 3⅞ per cent. The Government have offered other towns an opportunity of raising money for drainage purposes upon the same terms. We pay off 1-60th part of the principal each year. Then, if a work upon those conditions can be executed for a 6d. rate at starting, it is obvious that the next year 1-60th having been paid off there is less to be paid as interest, and each year it goes on decreasing the rate; then, whilst from that source there is a decrease in the rate, there is, on the other hand, an increase in the rateable value of most of our large cities by the increase in the cities, and therefore an increased fund for paying off the debt. Those two causes operating, very rapidly reduce the rate. In London we started with a 6d. rate, now we are down below a 3d. rate, and so it would be adopting that principle with any other large and improving town.

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641. How long is it since you started a 6d. rate?—About 15 years, I think. A 6d. rate at starting has done uncommonly well.

642. Have the Government made it a condition that the capital should be paid off in 60 years?—Yes.

643. Of course, where you take the land absolutely for your sewer you pay for it like any one else, I suppose?—Yes.

644. Will you just give me the measure of the mode of payment?—To a large extent we go through public roads and streets, and of course there is nothing to pay then. When we go through private property, we give the persons owning that property the power of building over our sewers. We, the Metropolitan Board of Works, put in the foundations for their houses, so that they should not interfere with the sewers.

645. Is that within your district as well as without it?—That applies to within our district only. Where we have gone beyond the district, we have in most cases purchased the surface; but the Essex Reclamation Company obtained in their Act the power to go through upon payment of easement.

646. In your sewers beyond the district, do you go on the surface for a considerable portion of their extent—in the marshes, for instance?—Yes, in some portions the sewers are above the surface.

647. Have you any case where, outside your district, you have a tunnelling under the land?—No; not outside our district. We have done an immense deal of work that we have never paid any compensation for. We have tunnelled from one end of Woolwich to the other; but at Woolwich we have never paid compensation for that, or easement of any kind.

648. Was that generally under roads?—No; a straight line.

649. Then you really have tunnelled under private lands without paying compensation?—We have. In paying easement, you must bear in mind that a sewer through an estate available for building enhances the value of that estate, and converts land which was previously not fit for building, into building land; and therefore, instead of paying easement, we have in many cases come to an arrangement to give them the use of the sewer.

650. Is there anything else that occurs to you?—I am not aware of anything else.

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651. *Sir John Hawkshaw.*—You are an eminent chemist. Will you give, in your own way, a short account of the process with which you are connected; first of all, what is the name of the Company?—The Native Guano Company, of which I am chairman. The process of purification adopted by the Native Guano Company is what is called the A B C process, but it has been very much modified of late years since I have been connected with the Company. The process consists essentially in mixing with the sewage a quantity of clay and charcoal in the form of an emulsion, and then putting in a solution of sulphate of alumina. The property of clay, when it is added in the form

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of an emulsion, is to keep in a milky state in the water, and not to settle; and the property of the sulphate of alumina, when that is added, is to cause this milky mixture of clay and water to coagulate, very similar to the white of an egg, which coagulates when it is boiled. In the act of coagulating, the clay carries down a great deal of organic matter which is in solution, a quantity of colouring matter, and a certain amount of ammonia from the solution. The sewage, besides, is always alkaline; and when sulphate of alumina is added to alkaline sewage, alumina is precipitated, and that also has a very powerful action upon dissolved organic matter. For instance, in the manufacture of colouring matters, what are called *lakes* among painters is the organic colouring matter of certain solutions, precipitated by alumina in the same way. The charcoal acts as a deodorizer, and prevents any smell coming from the mud. If the sewage is not alkaline enough to precipitate the whole of the alumina from the sulphate of alumina, lime is added; but great care must be taken not to add so much lime as to render it alkaline, or else the principle of the process is entirely altered, and it becomes then analogous to what is called the lime process; but if the lime is kept in insufficient quantity to precipitate the whole of the alumina, there can be no free lime in solution, and the effluent water remains slightly acid, which is what we wish to preserve.

652. Could you state, approximately, the cost of the process?—The cost of the process varies, of course, with the amount of purification required. At the present time the Corporation of Leeds are working the Native Guano process under licence from the Company; but as their officials are not quite so skilful at the process as they probably will be after they have worked it for a year or two, I go down occasionally and superintend operations, and try experiments to see if greater economy cannot be introduced. The amount of sewage at Leeds is an average of 12,000,000 gallons in the 24 hours, and it used to cost to purify, when they first commenced, at the rate of £50 or £60 a day, and the effluent that was produced was very good indeed. It was quite good enough to put into any river in the kingdom, except, perhaps, immediately above where water was drawn for drinking, and then, of course, it would not be recommended.

653. You do not put it forward as a potable water?—No, I should not recommend it as potable water, but it was just short of that—it was good enough to put into any river. The Corporation of Leeds were induced to adopt the A B C process, being under an injunction not to throw sewage into the river. The words of the injunction were somewhat to the effect that the sewage must not be put into the river so as to be a nuisance to the neighbourhood, or injurious to health. It was very soon seen when this beautifully clear water was being thrown in at a large expense that the terms of the injunction could be satisfied with a very much less amount of purity, and, of course, at much less expense; and the consequence was, they have been diminishing the expense, and, of course, diminishing the purity, at the expense of the system. But the river itself is so shockingly bad that it is a shame to put good water into it; it does no good whatever; therefore it is very fairly said, 'When our neighbours above Leeds send us decent water in the river, then it will be time enough for us to put in a better effluent; but as long as the river is nearly as bad as sewage, why should we put ourselves to the expense of several thousands a year extra to get a fanciful state of purity which does no good. We know that the process can give it when needed, but at present we will work the process in the most economical manner possible.' Of course, looking at it from the Leeds point of view, that is a very fair argument; but looking at it from my own point of view, as connected with the Native Guano Company, I naturally want to have the process worked to the best advantage, and I have been experimenting for some time past to see if by any modification of the materials or any alteration of the proportions I can get, without exceeding the limits of expense, a really better effluent than I thought I could get at first. I think now the effluent going to the river Aire is pretty good; there is no particular smell about it; fish could live in it; there is but little turbidity on standing; there is no particular taste; it does not putrify; and the expense of purifying the sewage to this degree is under £2 per million gallons.

654. That is, doing it in this method as you have described?—Yes, in this very economical way.

655. Supposing you wanted to do it to the utmost extent to which you, as a chemist, could say it could be fairly done by this process, what do you think would be the expense in that case?—At present it is costing about £22 or £22, 10s. a day of 24 hours. I should like to have an extra £5 or £6 a day, and I think that very great extra purity could be produced in that way; because when we get up to a certain point, a very little extra expense in sulphate of alumina, which is the chief purifying agent, does a great deal of good.

656. Do you work it both Sundays and week-days?—Yes, day and night. The Leeds Corporation say they will not spend more than £15,000 a year on the process. Of that £15,000 a year, £5000 goes on coals, and wages, and sundries, and things of that sort. £10,000 remains to be spent in chemicals, and that would be somewhere about £1 an hour, or £24 a day. I want to keep a little under the mark.

657. £22 a day is nearly £8000 a year?—Yes.

658. My question pointed to the total cost; supposing the process was carried to the extent to which you think it ought to be carried, supposing that the people above Leeds were doing what the people of Leeds are going to try to do,—that is to say, they were all compelled to purify the water and not to pollute the river above, and then that you were called in to prescribe what the Leeds people should do to deliver their water into the river equally pure to that which came from above, what would you then call the expense?—I do not think I should want much more purity than we get now. The expense now is, say, £24 a day for chemicals—I put it at £22, 10s., but £24 is the amount to allow, and probably it will amount to that taking the whole year; I think I should require another £5 or £6, making a total of, say, £30 a day for chemicals, or £11,000 a year, which, added to the £5000 a year for coals and all the other expenses, would bring up the total to £16,000 a year.

659. What is the expense of the construction of works, tanks, and buildings?—The expense, I think, would be about £60,000.

660. I think this process is very much the same, from your description, as that which they have adopted at Rio Janeiro. I was in Brazil last year and saw their works,—they are all new, and they have drained Rio and established these deodorizing works; and they are now using a method at Rio which strikes me as very much like yours,—they use sulphate of alumina, and they use lime also. I do not quite recollect about the clay?—The clay is an important element.

661. They may use it, but the water comes out clear and limpid water; but in draining Rio the whole town had to be drained *de novo*, and they have a separate system of sewage from the rainfall, and in that way not such a large volume to deal with?—Of course, if the rainfall can be separated from the sewage it makes the expense so much less.

662. The difficulty which they experienced here, and which we must always experience, is the stopping up of sewage drains,—that is to say, unless you admit a large quantity of water into the drains with the sewage, they are apt to choke up?—Yes; certainly that must be so.

663. You are aware of the various tests which have been suggested, some of them by chemists,—that is to say, taking the proportions of grains of certain elements per gallon, and so on; what is your opinion upon that method of governing questions of this sort?—I do not think that it touches the real point. For instance, water may be found to contain a certain fraction of a grain of organic nitrogen and of organic carbon, but this gives you no idea whatever of the kind of water.

It may be sewage, or it may be coffee, or beef-tea. The purest water—that is to say, perfectly pure distilled water—if you drink it, by the time it has got to the back of the mouth, contains more organic impurity than effluent water would contain to be condemned by those tests. I think it would be better to take such a test as it does not require a chemist to see. If a water is clear to the eye, has no offensive taste or smell, does not deposit a sediment on standing, and will allow fish to live and thrive in it, it is certainly good enough to go into a river, whether it contains much or little carbon or nitrogen.

664. Then, if you were proposing a test, that would be the way in which you would put it?—Yes; I should propose some such test, in addition to a chemical test. A manufacturer at Leeds has to take the river as he finds it,—he requires an immense quantity of water for his works. One manufacturer, I think, uses over a million gallons a day. If he takes that water from the river, he ought not to be obliged to throw it back into the river purer than he gets it; therefore the river itself should be the standard of purity. If that standard is adopted, every town would have a different standard, which is objected to by some persons, who say the standard should be uniform; but I think that that argument is not correct; because, if a person is near the head of a river, where he gets pure water, he ought to pay something more for that great purity; and that extra payment will be the additional expense he has to be at to hand pure water down to his next-door neighbour. This test of chemical analysis fails in another respect. Supposing a manufacturer is on the river Aire, where it is neither very good nor very bad water; he takes 100,000 gallons from the river, and puts it in the river just below the standard, so that it would not pass the standard; all he has to do is to turn a little more water into his works and dilute it with river water, and it will pass the standard.

665. You think it would be rather holding out an inducement to manufacturers to waste the water?—Yes; because when the river is passing through their works, or close to their works, it would be very little expense to turn more water through it to dilute the effluent water that comes out. There is another objection to this very strict standard that some chemists would impose. To make it of any use, it must be generally adopted throughout the country, and that would press very hard indeed upon all large towns situated at about the centre of a river, or below it. For instance, it would be absolutely impossible, I think, for the manufacturers at Leeds to carry on their business if they were obliged to put the water into the river as good as the chemical standard requires. They must either break the law or give up business. It could not be done practically, because the water is so bad to begin with, it is so far inferior to the standard proposed by the Rivers' Pollution Commission, that they could not purify it sufficiently.

666. But are you taking into consideration the possible circumstance that, beginning at the source of rivers or their tributaries, supposing each manufacturer was obliged to purify the water, and no longer to pollute it under certain restrictions, then of course the people of Leeds would not suffer as they do now—that is to say, if the people above them were all hindered from polluting the stream, the stream would come down then to Leeds in a purer state than it does now?—Certainly. The objection that I have to insisting upon this standard all over the country is, that it would press very hardly at first upon some manufacturers and not much upon others. Some rivers require a greater purity in the water that is put in than other rivers. For instance, I should insist upon a higher standard of purity for the Thames than for many other rivers. As it is, the Thames is under a different jurisdiction from other rivers; the Thames is under the Thames Conservancy, and other rivers will be, I suppose, under the Rivers' Pollution Commission, or under their standard. The standard of the Thames Conservancy is somewhat lower than the other standard. Some rivers which pass over pretty nearly all granite are very pure, with only a few grains per gallon impurity; and of course the standard for these ought to be very high. Every river should supply its own standard.

667. You mean that every river has its own character, and originally may not be so pure as another river, and therefore it would be unfair to make one standard apply to all rivers alike?—Yes. Then I think there is another view that has been rather lost sight of. We must think of the manufacturers on the river as well as the fishes in the river. It would scarcely be right to kill a manufacture—to destroy Leeds, for instance—for the sake of getting purity in the river. The manufacturers of Leeds declare that, under the circumstances, they could not purify the water up to the standard, and they say, 'We must either break the law, which of course we cannot go on doing for ever, or give up business.' That is what has to be thought of.

668. You can import your fish, but you cannot import your manufactures?—No; we are driving too many manufactures out of the country as it is.

669. Have you ascertained whether the effluent water from this process which has been applied at Leeds, after being allowed to stand for a considerable length of time, begins to smell again?—That depends upon how it is done. If it is in an open vessel it does not smell; if it is tightly corked up it will smell. I am speaking of water as it is turned out now, insufficiently purified; in a running stream it would not smell.

670. I asked that question because in a town where the process is being applied, and where I myself have seen the effluent water coming out of the premises where this process was carried on, it was at first pure, it had no smell, it was quite clear, and it was asserted had no taste. I did not myself drink it, but I was told that individuals had drunk it, and notwithstanding that, I was also told that after flowing down some four or five miles (it was a sluggish stream, no doubt, flowing but slowly) it began to smell again. Of course that would be over a long river a matter of considerable importance?—Would it not be difficult to know whether it was the actual effluent from the process which smelt, or something else in the river; because it would be very much diluted, I imagine, by the river water.

671. It was a small stream, you could scarcely call it a river, but about as wide as this room. That was told me by the borough surveyor himself, who was of course interested in making out that the process was good, and certainly it was good so far as regards the immediate operation of the process at the works; but he told me that after flowing five or six miles it began to smell again?—That might be the case; but I should say if such a thing were told me at Leeds or any place that I had under my own charge, I should conclude that something had gone wrong, and I should say, 'Let me come down and I will set it right.'

672. That does not apply to your process, it was simply the lime process.—There is an essential difference between the A B C process and the lime process. The effluent from the A B C process ought to be acid; the effluent from the lime process is necessarily alkaline, and anything that is alkaline putrifies readily. The great requirement of all processes is to keep everything acid; as soon as there is alkalinity anywhere there is putrefaction. The effluent from the lime process must necessarily putrify, and the mud must necessarily putrify; whereas the mud that we produce has no smell whatever. It can be thrown on to a field. I have seen a large tank, about 2 feet deep, covering a good fraction of an acre, filled with the mud in a fluid state and allowed to drain and dry in the sun till it cracked up, and could be carried away with spades and carts, and there was no smell whatever. You could not detect a smell by taking some up on a stick and putting it to your nose.

673. The distinction you draw is, that you think it probable that an effluent water which is alkaline might smell before long?—Yes. The effluent water from the A B C process, unless it is properly purified, will also smell if it is corked up in a bottle. The reason of that is this: there is always a certain amount of organic matter left in it; it is impossible to take the

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whole of the organic matter out unless enormous expense is gone to, which no town would submit to. This organic matter, when it is kept in the water free from the air, tightly corked up so that the water cannot absorb oxygen from the atmosphere, reacts upon the sulphate of lime, for instance, which is in the water, and reduces it to a sulphide; and the sulphide and carbonic acid liberate sulphuretted hydrogen, and that causes the smell. A great many mineral waters will smell in the same way if corked up. In fact, very few river waters will stand that test. The water supply of London would not stand that test. If you cork water up in a bottle for some time, and then shake it, you can always detect a smell.

674. Would you call the water of London alkaline?—It will be acid from the carbonic acid in it.

675. Supposing the pumping were to make the water absolutely pure,—that is, so pure that it would be potable, and anybody might drink it,—what do you say, as a chemist, would be the cost of doing it? In the first place, do you consider it is practicable to begin with?—I do not think it is practicable.

676. By any process that is known?—I do not think it is possible. The only chance would be by making use of the property which an alumina salt has of throwing down impurities, and trying whether putting more and more of it in would do good; then of the property which charcoal possesses of removing putrescible matter and removing the smell.

677. Supposing you were asked to attempt it, what do you presume would be the cost of attempting it?—The cost would amount up to anything short of infinity.

678. Apply it to Leeds, for instance.—It could not be done—it would be an impossibility to purify it properly. I can purify the water by this process sufficiently to pass the standard of the Rivers' Pollution Commission.

679. And supposing you were to apply it, what would it cost at Leeds?—It is nearly done now at Leeds. I think with the extra cost that I mentioned a little time ago it would be done; but then that would not give water which I should like to drink.

680. But you think it would be nearly up to the standard proposed by those chemists?—Yes. Dr. Letheby analyzed it a short time ago. The Leeds Corporation wanted to know how the process was going on without my being there. They thought that perhaps my being there kept the workmen rather closer to their work than otherwise; so, without saying anything to us in London, they gave orders that a sample of effluent should be taken several times a day and corked up in a bottle, and that should go on for a week. At the end of the week all those bottles should be mixed together, so as to get an average sample of the week's work. A bottle full of that was sent to Dr. Letheby, and he was asked to analyze and report upon it. Dr. Letheby gave results which, when compared with the Rivers' Pollution Commission, showed that it was superior to their standard in every respect except one; and I think a very little more purification would have removed that one point of inferiority. The Leeds authorities expressed themselves particularly pleased with the result of that test.

681. It would appear so far, then, that Dr. Frankland's standard was not so very wide of the mark?—It does not demand, as some persons say it does, a fanciful degree of purity; but the difficulty is to analyze water to that extent of minutiæ. The amounts that are sought for do not exceed the limit of experimental error.

682. Therefore you would have a considerable difference of opinion by employing a greater number of chemists?—Yes; it would be a fortune, in fact, for analytical chemists if that method was adopted.

683. You make a residue which you suppose in the course of time would be saleable. Could you form an idea of about the cost per ton of this saleable residue?—At Leeds they reckon that they will make about 12,000 tons a year, and they will pay for that £15,000. We maintain that that is a valuable manure.

684. That would not include the cost of works?—No.

685. You must add the interest of works upon that?—Yes.

686. That would be about £20,000 at least at Leeds?—Yes; say roughly 30s. a ton. But we reckon that it can be made for much less than that.

687. What do you suppose that it would sell for?—Our Company have sold about 4000 tons of it at £3, 10s. a ton.

688. At Leeds?—No; from different places. Where the sewage is from a residential town, with water-closets and no manufactures, the demand for our manure at £3, 10s. a ton is largely in excess of the supply; but in a place like Leeds, where the sewage is very much mixed with dye liquors and waste from manufactories, and where there are so many earth-closets and privies, the contents of which do not go into the sewers, of course the manurial elements are not in such excess as they would be in other towns. But the Corporation of Leeds tried some experiments on some land which they had. They took equal areas of land—I think half an acre—and put different manures on of the same value. They spent 30s. in native guano, taking it at £3, 10s. a ton; 30s. in stable manure; 30s. in Peruvian guano, and so on for several others; and I think the native guano came out best. It was equal to Peruvian guano of the same value. After that they advertised to the farmers of the neighbourhood that if they would send their carts to the sewage works, they should have a ton or half a ton, or whatever they liked, of the native guano, given to them for nothing, if they would try it on their fields and send reports to the Leeds Town Council. The reports are now coming in gradually. The last time I heard, twenty or thirty reports had come in, and about ten or twelve of them were favourable. A less number than that were unfavourable, and said that it was of no value whatever; others were, that they could not tell much one way or the other; but some of those reports which said that it was valuable put a money value upon it. Some said that it was worth £1 a ton, others said it was worth £2; another said it was very valuable indeed, but he put no money value on it. It was probably used for different soil and different crops.

689. What does Peruvian guano fetch a ton?—£13. It is rising almost daily now, and the standard is diminishing. They will not guarantee it now of the high standard that it was before.

690. Have you any idea at all what quantity of artificial manure is used in the kingdom? Are there any statistics to that effect?—There are statistics, but I do not remember them. I should think it would exceed a million tons.

691. Have you ever seen it stated?—I recollect seeing some statement of that sort, but I forget it at the moment.

692. Are you applying this process anywhere else except at Leeds?—No.

693. Do you know what they do at Bradford?—I do not. I think they are using the lime process, but I am not certain. We are negotiating with the town of Aylesbury.

694. Have you formed any opinion at all upon the irrigation system?—I have seen a good deal of it in Paris. They irrigated with a certain portion of the sewage of Paris an experimental farm in the plain of Gennevilliers, close to Paris. I saw a great deal of this a year or two ago, having to go there daily on matters connected with the sewage of Paris. The sewage farm was carried on by Government, and no expense was spared. They had plenty of labour, and they took the sewage when they liked and turned it away when they liked. The vegetables grew with the greatest luxuriance, but there was no firmness about them; for instance, I could thrust my finger right into the heart of a cabbage with the greatest ease; and if I took a vegetable, a cabbage or something of that sort, and broke it, and squeezed the juice out, I could always detect a sewage smell in the juice. Some quick-growing Italian rye-grass will take up actual sewage

into circulation. You can break it, and squeeze water out that has a decided smell of sewage. The earth that those plants were grown in was covered with a crust of the solid matter of the sewage that would not pass through the ground, and that crust smelt very badly indeed in the sun. The ground is as porous a soil as I should think it was possible to get—it is a very deep sandy peninsula. The process worked very well, I understand, for a few years; irrigation went on very well, but the solid matter of the sewage gradually choked up the upper portion of the soil, and then it was dug in and it worked better again for a short time; but in a shorter time it choked up again, and they were gradually getting the whole ground so clogged up that it would not filter.

695. What was the extent of the farm?—Nearly a hundred acres. Part of it was let out to different market gardeners to use. I think sewage irrigation might answer if a person might take the sewage just when he wanted it, and let it pass by when he did not want it; but to have to use the whole of the sewage I think would be a failure, because then the sewage must be taken not only in the summer, when plants can take any amount of water, but also in the winter, when vegetation is very sluggish, and when there is frost and snow on the ground, and also when there is a flood of rain.

696. Do you know what has become of the Barking farm, whether it is being carried on or not?—I do not know.

697. You would expect that the soil would deteriorate?—Yes, the soil will deteriorate—the filtering power will deteriorate.

698. You are aware, are you not, of Mr. Bailey Denton's proposal of deep drains and earth filters?—Yes. I do not think earth will filter sewage long. Sewage is the most difficult thing possible to filter. You cannot filter it through filtering paper; it contains a kind of glutinous papier-maché stuff which clogs up any filter.

699. You would expect those filters very soon to fill up?—Yes; they must not be so open that the solid matter in the sewage will pass through, and they will then be so close that they will soon clog up.

700. You do not believe in a filter of that sort answering in perpetuity?—No; it probably might answer very well for a few years.

701. Might not motion assist it?—Yes, that would renew the surface, but it would only delay the time that it would be clogged up. For instance, a good coarse sand will filter almost anything, and will allow almost anything to run through, but that very soon gets clogged up with sewage.

702. You would not expect much from the filtering process?—No, not after a few years' time.

703. With regard to the sewage of the Seine, do you know how far they take the sewage down the Seine?—It goes in at Clichy and St. Dénis, but all the solid matter goes to the forest of Bondy.

704. How do they separate it?—They have scarcely any water-closets; they have cesspits, which are emptied into closed carts which come round. A pipe goes down into the cesspool, a tap is turned, and the contents are sucked up into those carts. The carts are then taken to La Vilette on the outskirts of Paris. Boxes are placed underneath the closets in some of the houses to receive the fæcal matter and paper and things of that sort, and they also are carried to this same place. At Vilette the carts and boxes are all emptied into a large underground reservoir, where the semi-fluid excrements are well mixed up. From this there is a pipe five or six miles long to the forest of Bondy, and the whole of this fæcal matter is pumped through this pipe, where at Bondy it forms large lakes about the size of the Serpentine, and 20 feet deep, composed of nothing but the solid contents of cesspits.

705. What do they do with it?—They let it dry in the air for seven or eight years. In seven years' time the matter is sufficiently dry in those lakes for people to spread it about, when old women go over it for anything solid that there may be, and pick out the large corks and cleanse them, and send them back to Paris to be used. The dried powder is called poudrette, and is used as manure. It is worth going to Bondy to see that modern Lake Avernus; the smell is something so fearful, that few people can get within half a mile of it. The rain of Paris principally goes down the gullies in the streets; the street sweepings and the slops from the houses go in the same direction, and it is that liquid that was put on the plain of Gennevilliers, not the solid matter.

706. The tests which you have mentioned are matters which could be determined by the body in authority in a town, without aid in the way of any very skilful analytical chemists?—Yes. I should think that in a large town probably the officer of health, or some person like him connected with the Town Council, would be the person. At Leeds there is a Sewage Committee, which would be quite capable of judging of those standards which I think sufficient for the ordinary purpose of the water to be returned. In some cases it would be necessary to call in the aid of a chemist. For instance, arsenic must be kept out, and copper should be kept out, and certain metals that would be known to be coming in from the kind of works that were carried on in the neighbourhood. The water must not contain more than a certain quantity of free acid, and different things of that sort. There a chemist would be required; but in ordinary cases, where such special things are absent, common sense is much better than chemistry. I might observe, that after the effluent water passes through the works at Leeds, it passes through a pond of five or six acres, and a few feet deep. A part of this pond is to be planted with osiers, and in the pond is to be a considerable quantity of the American water-weed anacharis. This American water-weed will very soon fill up the pond, and will form the most efficient system of purification that can be adopted with the effluent.

707. You say that that particular weed has the quality of purifying?—It is a very gross feeder; it will live in any kind of water. In fact, any vegetation has a wonderfully purifying property upon water; it gives out oxygen in the water, and that burns up organic matter.

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RIVER CLYDE PURIFICATION COMMISSION.

PLAN Nº 1 REFERRED TO IN SIR JOHN HAWKSHAWS REPORT DATED MARCH 21ST 1876,
SHEWING THE INTERCEPTING AND OUTFALL SEWERS.

Note.—*The towns and villages are shown by circles, the areas of which are in proportion to the populations given in the census of 1871.*
The districts in the neighbourhood of the Sewers referred to in the Report throughout which coal and other minerals are being or may hereafter be worked are shown thus `.`.`.`.

Balfron
Endrick Water
Endrick Water
Kildean
Fenwick Water
BUSHBURN
Alexandria
Renton
Bonhill
Levenbank
Dumbarton
Milton & Eastfield
Old Kilpatrick
Milngavie
Kirkintilloch
Kelvin
River
Forth and Clyde Canal
Lennoxtown
KILSYTH
Auchinairn
Kirkintilloch
Hillend Reservoir
Rawyards
Clarkston & Draingellach
COATBRIDGE
AIRDRIE
Glenboig
Gartcosh
Cumbernauld
Dullatur
Bishopbriggs
Maryhill
Whitecrook
Hillhead
Renfrew
Yoker
Clydebank
Dalmuir
Duntocher
Kilpatrick
Loch Lomond
Loch Lomond
Loch Katrine
Loch Ard
Loch Chon
Loch Arklet
Loch Voil
Loch Doine
Loch Lubnaig
Loch Earn
Loch Venachar
Loch Achray
Loch Vennachar
Loch Drunkie
Loch Ard
Loch Chon
Loch Arklet
Loch Voil
Loch Doine
Loch Lubnaig
Loch Earn
Loch Venachar
Loch Achray
Loch Vennachar
Loch Drunkie
OUTFALL SEWER
OUTFALL SEWER
Water
Water
Water

SEWAGE DISPOSAL.

REPORT OF A COMMITTEE

APPOINTED BY THE

PRESIDENT OF THE LOCAL GOVERNMENT BOARD

TO INQUIRE INTO THE SEVERAL

MODES OF TREATING TOWN SEWAGE.

Presented to both Houses of Parliament by Command of Her Majesty.

LONDON:
PRINTED BY GEORGE E. EYRE AND WILLIAM SPOTTISWOODE,
PRINTERS TO THE QUEEN'S MOST EXCELLENT MAJESTY.
FOR HER MAJESTY'S STATIONERY OFFICE.

1876.

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EXPLANATION OF THE TERMS USED IN THIS REPORT.

SEWAGE.—The fluid refuse of a town.

SEWER.—The main conduit for sewage laid within a town.

DRAIN.—The tributary conduit for sewage from houses to sewers.

SEWERAGE.—A system of sewers.

RAW OR CRUDE SEWAGE.—Sewage as it flows untreated from a sewer.

CLARIFIED SEWAGE.— Sewage deprived of solids and flocculent matters in tanks.

PURIFIED SEWAGE.—Sewage filtered through land sufficiently to have neutralized the salts.

EXCRETA, used as a singular noun.—Fæces and urine combined.

DUST.—The ashes and other dry refuse from houses.

THE A. B. C. PROCESS.—Sewage treated with Alum, Blood, and Clay, &c.

M. AND C. PROCESS.—Initials of the patentees. The ingredients used are lime, carbon, soda, per-chloride of iron, and ashes.

THE PAIL AND GOUX SYSTEMS.—Moveable vessels placed beneath privy seats prepared to receive excreta.

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INSTRUCTIONS FOR INQUIRY.

(Copy.)

Local Government Board,
Whitehall, S.W.,
June 19th, 1875.

Sir,

I am desired by the President to enclose, for your information, a copy of a minute of the Board, dated 17th instant, directing an inquiry into the practical efficiency of the chief systems of sewage disposal now in operation, and for which loans have been sanctioned by this Department.

The President considers it desirable that the proposed inquiry should be undertaken as soon as possible, and I am therefore to request that you will be good enough to make the necessary arrangements for entering upon it in conjunction with the other gentlemen nominated by him. The principal points to which it is important that your attention should be directed are fully stated in the Minute.

I am, Sir,
Your obedient servant,
(Signed) John Lambert,
Secretary.

Robert Rawlinson, Esq., C.B., C.E.
&c. &c. &c.

SEWAGE DISPOSAL.

The attention of the Board has for some time past been directed to the great difficulties experienced by sanitary authorities in devising means for the disposal of the sewage of their districts; and, having regard to the frequent applications which are made to them for advice on this subject, they have deemed it expedient that special inquiry should be made under their direction into the practical efficiency of the chief systems of sewage disposal now in operation, and for which loans have been sanctioned by them.

The systems, to which the Board refer, are those for the disposal of sewage ;

1. By sewage-farms,
2. By land-filtration,
3. By precipitation and by chemical processes:

And in order that they may obtain reliable information as to the results of each of these processes, they have determined that Mr. C. S. Read, M P., one of their secretaries, and Mr. Rawlinson, C.B., their chief engineering inspector, in conjunction with Mr. Smith, the secretary to the late Rivers Pollution Commission, as their assistant, shall, as early as practicable, visit a limited number of localities in which the processes in question are in operation, and report fully to the Board thereon.

The points to which attention must be directed and upon which the Board are desirous of obtaining information, are mainly the following :—

1. The nature and character of the works and their actual cost; the rateable value of the district, and the population for which the works are available.

2. The length of time during which they have been in operation.

3. The effect of the works on the sanitary condition of the district, so far as it can be ascertained generally.

4. The efficiency or non-efficiency of the works as a means of disposing of the sewage of the district, and the quality of the effluent water in relation to its purification and deodorization.

5. Whether any nuisance is or has been occasioned by the works.

6. The annual outlay required for their maintenance and working, as distinguished from repayments of principal and interest, which should be shown separately.

7. In the case of sewage-farms, the acreage, description of soil, system of cultivation, the kind of crops, and the financial results.

8. In other cases the amount realized by the sale of the sewage.

The Board consider that at least four examples of each system should be included in the inquiry ; and they are desirous that the separate reports should be accompanied by a general report on the merits of the different systems.

(Signed) G. Sclater-Booth,
President.

Local Government Board,
June 17th, 1875.

TO THE RIGHT HON. GEORGE SCLATER-BOOTH, M.P.,
PRESIDENT OF THE LOCAL GOVERNMENT BOARD.

SIR,

HAVING in June 1875 received instructions to inspect examples of main sewerage outfall-works, so as to be enabled to report on the same, and to ascertain the facts as to sewage irrigation, we have visited Edinburgh, Wrexham, Chorley, Blackburn, Doncaster, Harrogate, Wolverhampton, Leamington, Warwick, Rugby, Banbury, Bedford, Croydon, Norwood, Reigate, Worthing, Aldershott, Romford, Tunbridge-Wells, Cheltenham, Merthyr-Tydfil, Barking, Norwich, and Enfield; Kendal, where the downward intermittent principle is carried out; Leeds, Bolton, Coventry, Tottenham, Edmonton, and Hertford, where sewage is treated by a chemical process; Bradford, Birmingham, and Luton, where sewage-sludge is precipitated by the addition of lime; and Halifax, Rochdale, Salford, and Manchester, where the pail system is partially used for dealing with excreta. We also visited Leyden and Amstersdam, where the pneumatic system is partially in operation; Paris, where only a portion of the sewage is utilised in irrigation; and Brussels and Berlin, where the sewage is about to be disposed of in irrigation.

We have obtained returns from the several towns visited as to their population, annual rateable value, the costs of the works connected with sewage treatment, the volume of sewage dealt with, and other details relating to the several points referred to in your instructional minute. The particulars thus obtained will be found in the following Report and Appendices 1, 2, 3, and 4.

The several Local Authorities, both at home and abroad, readily furnished such information as they had, and we required, and to them our best thanks are due.

Having examined the different modes of dealing with refuse, solid and fluid, in the several towns now reported upon, we beg to submit the following conclusions.

CONCLUSIONS.

1. That the scavenging, sewering, and cleansing of towns are necessary for comfort and health; and that, in all cases, these operations involve questions of how to remove the refuse of towns in the safest manner and at the least expense to the ratepayer.
2. That the retention for any lengthened period of refuse and excreta in privy-cesspits or in cesspools or at stables, cow-sheds, slaughter-houses, or other places in the midst of towns, must be utterly condemned; and that none of the (so-called) dry-earth or pail-systems, or improved privies can be approved, other than as palliatives for cesspit-middens, because the excreta is liable to be a nuisance during the period of its retention, and a cause of nuisance in its removal; and, moreover, when removed leaves the crude-sewage, unless otherwise dealt with by filtration through land, to pollute any watercourse or river into which such sewage may flow. We have no desire, however, to condemn the dry earth or pail systems for detached houses, or for public institutions in the country, or for villages, provided the system adopted is carefully carried out.
3. That the sewering of towns and the draining of houses must be considered a prime necessity under all conditions and circumstances, so that the sub-soil water may be lowered in wet districts, and may be preserved from pollution, and that waste-water may be removed from houses without delay; and, that the surfaces and channels of streets, yards, and courts may be preserved clean.
4. That most rivers and streams are polluted by a discharge into them of crude-sewage, which practice is highly objectionable.
5. That, as far as we have been able to ascertain, none of the existing modes of treating town-sewage by deposition and by chemicals in tanks appear to effect much change beyond the separation of the solids, and the clarification of the liquid. That the treatment of sewage in this manner, however, effects a considerable improvement, and, when carried to its greatest perfection, may in some cases be accepted.
6. That, so far as our examinations extend, none of the manufactured manures made by manipulating town's refuse, with or without chemicals, pay the contingent costs of such modes of treatment; neither has any mode of dealing separately with excreta, so as to defray the cost of col-

lection and preparation by a sale of the manure, been brought under our notice.

7. That town-sewage can best and most cheaply be disposed of and purified by the process of land irrigation for agricultural purposes, where local conditions are favourable to its application, but that the chemical value of sewage is greatly reduced to the farmer by the fact that it must be disposed of day-by-day throughout the entire year, and that its volume is generally greatest when it is of the least service to the land.

8. That land irrigation is not practicable in all cases; and, therefore, other modes of dealing with sewage must be allowed.

9. That towns, situate on the sea-coast, or on tidal estuaries, may be allowed to turn sewage into the sea or estuary, below the line of low-water, provided no nuisance is caused; and, that such mode of getting rid of sewage may be allowed and justified on the score of economy.

ROBERT RAWLINSON.
CLARE SEWELL READ.

S. J. SMITH, *Assistant*,
21st July 1876.

REPORT.

A statement of facts connected with the treatment of sewage at any one town or district can only have a certain limited value, which will be in proportion to the efficiency of the system and the accuracy of the description; but any single example may not have much value outside of the special conditions of the locality. We have investigated examples of the waste of sewage into the sea, of its treatment in depositing tanks without chemicals, of its treatment in depositing tanks with a use of chemicals, of its application to land in irrigation, by gravitation, and of its application to land by pumping. We have also examined several modes of removing excreta in pails, as at Rochdale. Reports more or less in detail of the several processes are given in the Appendices Nos. 1 to 4.

Modifications in the Volume and Constituents of Sewage.

The volume and constituents of sewage are modified by :—

1. The surface contour and local rainfall;
2. The geological character of the substrata, the mode of forming the surface roads and streets, and the amount of local traffic ;
3. The volume of water-supply, the mode in which it is applied, and the volume of subsoil-water taken into the drains and sewers ;
4. The mode and efficiency of the main-sewering, house-draining, and the way in which waste-water and excreta are disposed of ;
5. The efficiency, or otherwise, of surface scavenging and sewer and drain flushing.

Steep surface gradients and roads and streets macadamized, defectively scavenged, and over which roads and streets there is an excess of quick traffic, as cabs, omnibuses, and vans, will send much detritus into the sewers. Birmingham is an example of all the above-named conditions, and consequently also an example where the solids washed down to the outlet are in excess.

The volume of water supplied and passed into sewers, with the volume of subsoil-water entering them, will, during all ordinary periods, constitute the volume of sewage to be dealt with ; and as drains and sewers usually receive a portion of the rain, there will, in wet periods, be this volume extra to provide for.

Sewers and drains which have been properly designed and well executed transmit sewage day by day as generated, so that it is fresh, and not putrid ; and in the treatment of sewage by any process it is of the utmost importance to deal with it fresh, as there will be less cost in chemicals (if such are used) and less nuisance on the surface of the land if the sewage is applied in irrigation.

In a town properly sewered and drained, well supplied with water on constant service, and wholly water-closeted, the sewage will be in the richest state, and may be dealt with at the least cost and with the greatest safety to health, either by chemicals or by irrigation over land.

In a well sewered town the character of the sewage will vary in proportion to the time of day and to the habits of the population, as it will be richest in the morning, at noon, and in the evening. From midnight to early morning, for six or eight hours, the sewers will contain little more than subsoil-water and waste from defective water-supply fittings.

Towns which are defectively sewered, and in which there are many privies and ashpits drained into the rudely-formed sewers, have sewage in its most offensive and dangerous form ; and if such sewers are defectively ventilated, there will be the greatest element of danger to health. To connect dwelling-houses with such sewers by drains, especially if the drains are not ventilated, is to incur the greatest risk of danger to health.

Towns in which the so-called dry modes of treatment, or the pail systems prevail, retain human excreta for a longer or a shorter

period, as where the pails are said to be removed and emptied each week (that is 52 emptyings each year); or as in portions of Edinburgh, where the pails are said to be removed from room tenements each day, or (excluding Sundays) 312 times in the year. The wholesomeness of this treatment must depend more upon the absolute and perfect cleansing of the tubs or pails at each removal than upon the time of retention, as foul pails will become putrid, and the leaven of putridity will be communicated to the refuse as it is deposited in the pail, or tub. The cost of collecting and replacing the pails is necessarily in proportion to the convenience for removal and the distance of the depôt. The yearly cost of collecting the pails in Rochdale and of working the contents into a solid manure is about 11*s.* 1¼*d.* per ton.

The yearly costs of manipulating the solids of sewage by mechanical and chemical means are set forth in the abstracts from the reports on Coventry, Birmingham, Bradford, Halifax, and Leeds.*

Chemists' Estimate of Town Sewage not its Value to a Farmer.

With respect to the laboratory value of town refuse and of sewage, or of the manipulated solids of sewage, we do not know of a single case where it is sold at a profit; and, as a consequence, there has been local disappointment and accumulations of several thousands of tons of manufactured manure, asserted to be worth from one to several pounds sterling per ton, which prices are not realized; consequently there are these vast heaps encumbering the premises where manipulated. In the case of town sewage, we find that its unceasing flow and the great volume of water to be disposed of day by day, detract from the undoubted manurial value which there is in it, so that sewage containing ammonia, representing a manurial value of 2*d.* per ton, has to be given away, or has to be wasted into the sea. With respect to the solid manure made from town refuse and extracted from sewage, its bulk and weight reduce its value, and, as, like sewage, the production goes on all the year round, it must be heaped up until farmers can be induced to remove it—the inducement for them to do so being a price far below the cost of production.

See Analyses, pages lxi, lxii, lxiii.

Town Scavenging.

Town refuse, both fluid and solid, must be got rid of, and the more completely and rapidly the process is effected the better will it be for the inhabitants. The cost of any process should, however, be a secondary question—always provided that due skill has been, and is used in devising the local works, and proper care has been, and is exercised in supervision and labour.

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* Note.—The tank mode of treatment costs about 150*l.* per annum for 100,000 gallons of sewage per day so treated, plus the interest on the cost of tanks and apparatus.

With respect to town scavenging, the ashes and other waste refuse will have most value when retained dry, and that town will be best served where the removal is regular, and at short intervals, by dust-carts, into which the dust is discharged direct. It is a dirty process to empty dust on to the street-surface to be shovelled up by the men after some of it may have been blown about.

Town Sewering and House Draining.

Town sewering and house draining are as ancient as civilization. Drain-tubes of earthenware have been found under the mounds of the ruins of the cities of Asia. The Romans sewered their cities and towns, and drained their temples, baths, and public buildings, and the sewage polluted the adjoining rivers.

Sanitary progress in Great Britain is recent, and the first rude sewers were more mischievous than beneficial. The earliest Norman castles were not sewered, but were sinks of filth both within and without. One of the earliest improvements was the Guarderobe turret or tower, constructed in an external wall, the floor being carried over the outer face upon corbells. This floor was dished from the sides to a central opening from which excreta could fall outwards to the base of the castle wall. Some of these Guarderobe towers were removed from Windsor Castle since 1840. About the beginning of this century waterclosets were re-invented and were introduced into better class residences, the drainage from them being to the nearest sewer or from the house to some ditch or watercourse or to a pit, or even over the surface of the ground or into the side-channel of a public road. In London and some other towns the nuisance arising from waterclosets was found to be so great that Improvement Acts were obtained in which clauses prohibiting a use of public sewers for waterclosets were inserted. The old sewers were large, rude in construction irregular in gradient, having flat bottoms and being unventilated, so that every form of refuse passed into them remained to putrify, ferment, and exhale gases of a deadly strength, and on some occasions men on entering to cleanse them fell dead. The comfort and convenience of waterclosets having been experienced parties using them did not like to give them up, and as they were not to use the sewers, they were ordered to construct absorbing cesspools into which the contents from the waterclosets were to be emptied, and cesspools were constructed within the basements, yards, and gardens of London houses by tens of thousands, some larger houses having several. In course of time an overflow from a cesspool, cesspit, or ashpit, was permitted to connect with a sewer. This is the position of things now in Birmingham, Manchester, and most of the large towns of Lancashire and Yorkshire. At Windsor Castle, so recently as 1850, there were 53 cesspools within the basement all full and overflowing. This cesspool plan is in favour and full practice in continental cities and towns, as at Paris, at Brussels at Ostend, and at many other continental towns. In Holland, the rivers and

canals are the main-sewers, as, also the main sources of water-supply for domestic purposes.

At Paris and at Brussels main intercepting-sewers have been constructed, in both of which cities as in London, the sewage flows into the rivers to their serious pollution.

In Holland the pneumatic system has been partially adopted. Frankfort on the Maine has been sewered, and the houses are being drained on the English plan. In the suburbs of Paris sewage irrigation has been partially established, and more complete works of sewage utilization are contemplated. In Brussels there is a very small trial work, and Dantzic has also been sewered on the English plan, and the sewage is applied in irrigation for agricultural purposes. See Appendix No. 5, page 73, Privy system.

Sewage varies in Quality.

There have been many hundred analyses made of town sewage, and its value is stated to be in proportion to the ammonia found in it. Samples of sewage vary from less than 2½ to upwards of 15 grains per gallon, and the chemist's value is one fourth of a penny per ton of sewage for each grain of ammonia in one gallon. The most important element in sewage is the nitrogen, in the state of ammoniacal salts; or, in combination with organic matters as nitrogenous matter. The nitrogen of ammonia is, however, immediately available to vegetation, whilst that which is combined with organic matter only becomes so gradually, through decomposition. Sewage is rich or poor in proportion to the number of waterclosets used and connected with the sewers, and the state of dilution. An extravagant use or waste of water and an excess of subsoil-water seriously increase dilution. Admission of surface-water will also tend to further dilution. But water has value when applied to land in irrigation, and there are cases where extreme dilution of the sewage is not objectionable; as where the land irrigated is highly absorbent, is of sufficient area, and is under grass. Pumping to a moderate elevation—50 feet or under—is not necessarily costly, as we see that 977,470 tons are pumped at Doncaster to a head of 52 feet at an annual working sum of about 300*l.*

Sewage difficult to deal with.

Sewage as it flows from well-constructed drains and sewers contains much flocculent matter and solid detritus, which in some cases, as at Birmingham, is separated in tanks, to the extent of 109,500 tons per annum, and which sludge is difficult to manipulate, impracticable to dry, and unsaleable. Precipitation by the use of chemicals is carried on at Leeds, Bradford, Halifax, Bolton,* and at other places, as detailed in this report. In some cases there is little or no separation, as at Aldershot and Chorley, where the sewage flows direct on to the land; and at Leamington, Warwick, Bedford, Banbury, Worthing, and Doncaster, where crude sewage is pumped and delivered by carriers over the irrigated lands.† Where

* Note.—Appendix No. 3, pages 33 to 56.

† See Appendix 1, pages 1 to 30.

the permanent sewage-carriers are duly proportioned to the volume of sewage, and are of iron, of earthenware, of concrete, or of other solid material, there is no retention of sediment, and consequently, no permanent nuisance as is the case in the large, rude, and foul open sewage-carriers at Edinburgh.

Proportion of Sewage to Excreta by Volume and Weight.

A population of 100,000, exclusively using waterclosets and producing 2,500,000 gallons of sewage daily, may be contrasted as under, to show the relative volume and weight of the sewage, the urine, and the fæces. In a mixed population of both sexes and all ages the excreta of each person per day has been found by experiment to weigh $2\frac{1}{2}$ lbs. A gallon of sewage weighs, say, 10 lbs.; 2,500,000 gallons therefore equal 25,000,000 lbs., and the excreta of 100,000 persons equals 250,000 lbs., or the proportion is as 1 to 100. The urine of 100,000 persons weighs 234,380 lbs., and the fæces 15,620 lbs.; the solids (fæces) being by weight and volume to the sewage in the proportion of 1 to 1,600. The so-called solid portion is to the fluid or urine as 1 to 16, that is, ounces to pounds.

Where human excreta is retained within houses and towns until it is removed by hand labour, or even by special contrivances, there must be a certain amount of inconvenience experienced which will be annoying; and as there is and must be a vast amount of labour expended to remove such refuse, the process will be costly, the relative cost being set forth at page 68 of the Appendix.

In all the so-called dry processes (which are not dry) there is with the excreta a considerable volume of urine and water. This is so in the pail system, and in every form of improved privy.

The advocates of these systems declare that they are aware that town sites must be sewered and that houses must be drained, if only to remove subsoil-water, surface-water, the waste-water used by the inhabitants, and the drainage from stables and privy ashpits. This subsoil-water, surface-water, and waste-water from dwelling-houses, stables, cow-sheds, slaughter-houses, and local manufactures must be treated in the same manner as sewage, before it can be permitted to flow into streams and rivers. The excreta is, however, separated under the idea that there will be more value obtained as manure, and that there will be less pollution at the outlet of the sewers. Experience and analyses show that such conclusions are erroneous. There are in manufacturing towns many sources of pollution other than the drainage of houses, of ashpits and cesspools, of cow-sheds, of stables, and the washing of the streets' surface; and in many cases this liquid will have to be provided for in the sewers, as at Coventry, at Kendal, and at other places. Sewers ought, in fact, to receive all water polluted by ordinary processes, as analysis proves that sewage is very little less polluted by the exclusion of human fæces. The Rivers Pollution Commissioners state (pages 29 and 30, Report, Mersey and Ribble

Basins) that 12 tons of average sewage from a midden and privy town will in round numbers equal 10 tons of sewage from a watercloseted town in manurial value, so that the mischief, cost, and intolerable nuisance of a retention of the privy system—and this also is applicable to all so-called dry systems—only reduces the strength of the sewage by two sixths.*

Sewage not Profitable to the Extent Estimated.

In 100 tons (224,000 gallons) of sewage, having the equivalent of eight grains of ammonia to the gallon, the ingredients are estimated as having a manurial value of 17*s.* 7*d.* The suspended matter, which will subside when at rest or which chemicals will assist to precipitate, is worth 2*s.* 2½*d.*; other dissolved matter which remains in the clarified water being worth 15*s.* 4½*d.* This makes the value 2·1 penny per ton, or say 2*d.* per ton, the Royal Commission (1858 to 1865) accepting this estimate of 2*d.* per ton after a set of exhaustive experiments fully recorded in their three Reports,† came to the conclusion that a farmer having to take and dispose of sewage day-by-day all the year round would not give more than a halfpenny per ton, if even this could be afforded. An examination of the abstracts in this report will show that sewage has very generally been used in irrigation at a loss.

Although this estimate appears so favourable we find that it fails to be commercially productive in practice, and we may again repeat that no chemical or other treatment of town-sewage with which we are acquainted is a commercial success; the suspended solids may be precipitated and the sewage so far clarified by these processes, but the sewage is not purified nor does the sludge appear to be increased in value as a manure so as to command a sale sufficient to pay the costs of production.

The pail system, as practised at Rochdale and other places, does not produce a solid manure of sufficient value to repay the contingent expenses, and command a ready sale.

Sewage not to be stored in Cesspools.

Sewage should not be stored in cesspools beneath houses, or near to houses within a town, neither should it be allowed to rest stagnant in badly formed sewers, nor, indeed, in any sewers; but all waste-water and excreta should pass to the drains unperceived, and should then flow in an unceasing stream; and, if practicable, at once over and through land properly prepared for its reception and agricultural use.

Mechanical Power of Water.

Water is a purifier, a cleanser, a dissolver, and a mechanical power, and will carry along down an incline the solid ingredients

* Note.—There are recent privy arrangements to intercept urine. The game will not, however, be worth the candle.

† Note.—See Appendix No. 7.

of town sewage, with road detritus, such as grit and silt; the moving power of water being in proportion to the volume, the vertical depth, and the gradient down which the flow is directed. Flushing by volume and head artificially formed will remove detritus from sewers of low gradients where accumulation may have taken place. A velocity in the sewage of two feet six inches per second will remove any solids likely to be passed into drains and sewers.

The weight of detritus and silt moved along with and by the metropolitan sewage is not so great as in some other towns, such, for instance, as Birmingham and Leeds; because in London much of the sludge is removed from the street gulleys and much is removed from the old flat-bottomed sewers by hand labour. In the aggregate a large weight of detritus is, however, swept along to the outlets, and is discharged into the Thames at Crossness and at Barking.

General Remarks on Sewage.

The mode of utilising sewage with economy must depend upon local conditions, and a waste of sewage (which is manure) can only be justified when it would cost less to waste it *harmlessly* than to utilise it, as at Edinburgh, Liverpool, and Brighton, for instance. At Edinburgh the Craigentinny meadows afford the strongest example of pecuniary success in the rough and ready use of crude sewage to produce rank crops of grass; and at Edinburgh also, in the Water of Leith intercepting-sewer we have an example, on a greater scale, of a waste of sewage into the sea at the Black Rocks outlet. The cases must, however, be considered with all their surroundings. At the Craigentinny meadows crude sewage flows down from the older part of Edinburgh without stint or charge towards land having little value in its natural state, as it is for the most part blown sand from the adjoining estuary. This sewage is received at a point sufficiently elevated to allow of its gravitating on to the land to be irrigated. It flows into rudely formed open carriers, to the highest points of the estate, from whence it gravitates by cheaply formed sub-carriers over the land below, the effluent escaping down to the boundary line of the sewage farm, which is the sea. The land is of low value as agricultural land; the sewage is abundant, far more than is required for the area irrigated; it costs nothing to the proprietor of the land; and its use, its abuse, or its waste is under no local control; it is applied in the cheapest way, and the crops are put up to auction in one acre plots each year, the purchaser cutting and removing the grass at his own cost. The mode of irrigation is uncleanly and rude, and there is undoubtedly at times an offensive smell from the carriers, from the rudely drenched irrigated surface, and from the effluent water. During winter the sewage is allowed to flow direct into the sea.

Sewage Irrigation proved not to be injurious to Health.

There is no record of any special outbreak of disease at or near the sewage farm. The men working on the land and amongst the sewage are reported to be healthy, the men cutting the grass are healthy, and the cows fed upon the grass are also as healthy as other cows, producing wholesome milk; and with respect to tapeworm, the medical men who attend the Edinburgh hospitals do not find any exceptional excess of this disease amongst their cases; but, on the contrary, less than in other hospitals. The Craigentinny meadows were made the subject of an exhaustive inquiry by the War Department during the time that Lord Macaulay was member for Edinburgh and Parliamentary Secretary for that department. Complaints were made that the proximity of the irrigated meadows and the effluvium from them produced disease in excess amongst soldiers quartered in the neighbouring barracks. Official inquiry was made by army medical officers, who took the returns of health and mortality for 20 years back from barracks situate in different parts of Great Britain where troops similar in numbers and performing similar duties had been quartered, and these returns were tabulated, the results obtained proving that the barracks adjoining the Edinburgh sewaged meadows had the lowest sick and death rate in the list, so that the allegations against the Craigentinny meadows fell to the ground.* It must not, however, be supposed that rough and ready sewage irrigation is advocated, as the evidence should only be taken as proving that the application to land of putrid and crude sewage in the most gross form does not necessarily breed a local pestilence, though such mal-arrangements may produce an offensive nuisance which ought not to be continued. But we have no evidence that these Edinburgh meadows are a nuisance injurious to health; we are, however, satisfied that the work of irrigation may be carried on in a manner much more cleanly by a construction of settling-tanks to separate the solids and by the construction of permanent main-carriers, which could be regularly cleansed. The utilisation of sewage should, in all cases, be carried on in such manner as, in the vicinity of dwellings, to be the least offensive, although additional costs may, in some cases, be incurred to pay for more complete purification.

Money Returns from Sewage contingent on Local Conditions.

The tabulated statements now made from experiments with sewage on a great scale show that money returns are contingent upon local peculiarities and management. Where the works necessary to treat sewage are simple in their construction and the treatment is unfettered by patents, there is least loss. Purification of sewage is not, however, effected by any use of chemicals which has been brought to our notice, the result in all cases having been

* See also Appendix No. 5, pages 102, 103.

clarification only; that is, a better separation of solids and flocculent matters held in suspension; seven-eighths of the salts of sewage remaining in the clarified water, so that the pollution of a small river or watercourse would not be prevented, however perfectly the sewage may be clarified, as was proven at Leamington, Blackburn, and Cheltenham, where the salts in the clarified sewage combining with the earthy matters on the beds of the streams, fermenting gave out offensive gases sending to the surface a black and putrid scum. We have no reliable evidence that the solids extracted and made into a portable manure have any paying commercial value. At Birmingham, as will be seen by the returns, there is now no serious attempt to sell the sewage-sludge, but it is at great cost, 14*l*. 10*s*. per acre, dug into a portion of the farm-land at a rate of about one acre per week, or at a loss of about 750*l*. a year. At Leeds, Bradford, Bolton, and at Coventry thousands of tons of extracted sewage-sludge remain to cumber the works.

At Halifax and Rochdale, where the pail system is in operation and the excreta is collected by hand and mixed with house-ashes, there are also thousands of tons of the prepared manure in store, because a ready sale of it cannot be effected.

At London, about 600,000 tons per day of the richest sewage in England is poured into the River Thames; at Edinburgh, the Water of Leith sewage is wasted into the sea, and this is also the case at Liverpool, at Brighton, and at most of the large towns in England and Wales which stand upon a river-estuary, or fronting the sea, as at Swansea, at Scarborough, at Sunderland, and Newcastle-upon-Tyne, and at other places.

The Pneumatic System.

One of the most complicated and costly processes for dealing with the solid of human excreta (not with town sewage), is the system known by the name of the inventor, Capt. Liernur.

The pneumatic system has been partially introduced at Leyden, Amsterdam, and Dordrecht, where we have seen it working. These towns are flat and are intersected by canals and open watercourses. The towns are not sewered on the English plan, but have surface gutters along the margins of the footwalks into which surface water flows and the inhabitants throw their waste water and liquid household refuse. There are inhabited basements below the level of the streets and gutters—in some streets the gutter is square on section—close to the basement entrance, and covered by a lid of timber which can be raised by the householder for the purpose of discharging slop-water into the channel which communicates at short intervals with a river, canal, or watercourse, as one or the other may be available. There are also small and short surface-drains opening into the watercourses as above described.

At present the excreta in these towns passes from the house-drains into the rivers, canals, and watercourses; the ashes and vegetable refuse being collected from tubs and boxes by what we

in London term *dust carts*. The rivers, canals and watercourses bordering and intersecting the Dutch towns are made into open sewers. Waterclosets on the English plan are used to a limited extent. A modified privy is however generally arranged within the houses over a vertical shaft which drops the refuse to a drain below. In many cases chamber utensils are used. The Dutch towns are deficient in water supply, so that, almost throughout the country, water from rivers, canals, or the watercourses is used for all domestic purposes, however much tainted it may be.

The country being so flat, so intersected by rivers, canals, and watercourses, and the land and street surfaces so little above the general level of the water, has induced the municipal authorities of Holland to come to the conclusion that main-sewers and house-drains, as constructed in English towns, are impracticable; hence the resort to the pneumatic system.

Capt. Liernur acknowledges that towns should have the subsoil water lowered, that they must be sewered, that houses must be drained, and that the fluid refuse of manufactures must be provided for, but insists that human excreta must be removed by separate and costly apparatus, consisting of steam-engines, air-pumps, iron tanks, and cast-iron pipes of five inches internal diameter—none more, none less—these pipes to be jointed as if for carrying water under high pressure. These pipes are not, however, laid in level and right-line lengths, but in the form of saw teeth extended, so as to break the line of pipes vertically into long downward slopes of 1 in 250, and short upward slopes of 1 in 5, the long slope and its short upward slope forming a sort of inverted syphon, where sewage must rest and block the pipe, to be sucked upwards and forwards by the partial vacuum. The soil-pans are not much unlike English waterclosets; they are fixed beneath a seat, have a syphon bottom outlet, and are specially ventilated. These pans are fixed within buildings as waterclosets are fixed, and are used as waterclosets are used; the prime difference being that the user of the pneumatic closet has no power of emptying the pan. In some cases, where a closet is liable to be much used, the pan has been filled above the brim, and the air-suction failed to empty it. In all cases the closet is a fixed receptacle, amenable to no control by the users, but dependent for its action upon a perambulating turncock. If servants disobey rules and pour in slops or the contents of chamber utensils, and the pan is full before the time of turning on the vacuum comes round, full it must remain; and if there is overflow the nuisance must be endured. This would be found intolerable in English houses, where the perfect control of the watercloset rests with the user. Capt. Liernur proposes refinements, such as a moveable lining to his pan, that it may be cleaned, which is unnecessary in the English closet. Additions to the receptacle, in the form of a self-acting shallow pan apparatus to contain a small volume of water, is to be added; this shallow pan to hang vertically when not in use, but to rise into a horizontal position so as to form a false bottom when in use. Standing in front of the seat is to raise the pan and fill it with

water; moving from the seat is to permit it to fall down again and discharge the contents. Our experience is that self-acting apparatus soon ceases to have any action. The excreta which is pumped to the central station is in a fluid state necessarily, and is put into barrels and sent away to the country, involving trouble, cost, and inconvenience in several forms. The manure is too rich to distribute over grass-land in very dry weather without dilution, and it is too bulky to carry long distances. It is proposed to dry it; this process must, however, greatly reduce any remuneration to be obtained by sale. At present farmers have tried the manure, and have paid at a rate of 8*d.* per 32 gallons, or 6*s.* 8*d.* per ton; but this price was soon abandoned, the price being reduced to 2*d.* per 32 gallons, or 1*s.* 8*d.* per ton; and ultimately, after further trial, this arrangement ceased, as it was found to be necessary to remove the excreta daily or at other short intervals, because it was not convenient for the farmer either to store it or to use it; and in winter, during frost, the barrels in store were frozen and burst.*

Remarks on the Pneumatic System.

Captain Liernur has been particularly fortunate in having the manure which his system produces tried in Holland, as the use, application, and storage of liquid-manure is much better understood there than in England. A considerable number of the farmers in Holland grow no straw, consequently, the manure made by the cattle in winter has to be utilized in a liquid state. In England this liquid-manure is generally absorbed by the straw, or by other bedding upon which the cattle stand. Some 20 years ago there was a general movement amongst English farmers for applying the drainage from farm-yards to the land, and tanks, pumps, and liquid-manure carts were, for a time, in great request; but the application of this farm-sewage produced so little result in proportion to the cost, that pumps and carts for this purpose are now seldom used upon arable farms. We are confident that the liquid which is collected at such cost in barrels would find no ready sale in England, even at a very low price, and we further believe that any English farmer agreeing to take it continuously from any town would not only not pay anything for it, but would certainly charge something considerable for his trouble and for the expence of removal.

If the towns of Holland, or portions of such towns, by reason of peculiarities of site and climate, cannot be sewered on English principles, and if the pneumatic system is as cheap as any of the moveable pail systems, it may be the best under such conditions for Holland, because if worked in accordance with the rules laid down the excreta will be removed daily without the intervention, trouble, and dirt involved in the pail system. The pneumatic system only deals, however, with a small fraction of the refuse to be removed from houses leaving all other forms of refuse to be dealt with in the ordinary way, so that Dutch town-sewage must flow into the rivers and canals as now, to pollute the water-supply; or,

* Note.—See Appendix No. 4, pages 61 to 70.

some complicated mode of intercepting it must be provided at an additional cost to the local authorities.

The pneumatic system is ingenious, but it is complicated in its construction and working arrangements; and, consequently it is liable to derangements which are sometimes difficult to mend. We do not know one English town in which the apparatus if adopted would be other than a costly toy.

As may be imagined, when the nature of the arrangements and complications are considered, the pneumatic apparatus gets out of order, the slightest crack in any pipe or pipe-joint will reduce the force of the partial vacuum, and even where all the apparatus remains sound the closet-pans may not be emptied; and, in fact, neither the pipes nor the pans ever are entirely emptied. The power of air and water to remove solids through pipes being as their relative weights and velocity, and air is to water, by weight, about as 800 to 1.

Town Sewage: Its Treatment and Characteristics.

Town sewage is water holding in solution and having in suspension certain ingredients which render the water objectionable to the senses of sight and smell and unfit for domestic purposes.

The volume of sewage in any town is in proportion to the water used and expended for domestic and manufacturing purposes, with subsoil-water and occasional dilution by rain.

Where waterclosets are in general use human excreta is added; but though this in itself is rich in manurial ingredients and is also liable to become highly polluting, it must ever be a small fraction of the whole volume of sewage—about one hundredth.

In the manufacturing districts sewage is largely mixed with the waste ingredients used. Skinners, tanners, dyers, bleachers, brewers, brassfounders, tinplate makers, japanners, wool and woollen goods washing and scouring, chemical works, and paper works, with other forms of manufactures, pollute large volumes of water, to the extent of entire rivers, as in the Aire and Calder in the West Riding of Yorkshire, and in the Mersey and Ribble basins of Lancashire. In the 6th Report of the Rivers Pollution Commission, 1874; a map shows the several localities.

All chemical treatment of sewage, by patented processes or otherwise, aims at deodorisation; that is, at clarification and purification. The processes are reported to take from sewage turbidity, colour, and scent; but no such process has ever restored sewage water to its original purity, though most of the suspended solids may have been removed, the salts of sewage remain, and generally some of the chemicals, mixed with the water.

The sewage of a town, in which there are no manufactures or dyeworks, is a turbid liquid, bluish grey in colour, having the scent of stale cabbage water rather than of human excrement; in warm weather stagnant sewage becomes offensive, having the stench of rotten eggs; when allowed to stand exposed it does not become clear, but ferments, and if confined in sewers or covered

tanks becomes dangerous to human health, though not to such an extent as the offensiveness may be taken to indicate. When at its worst, on being brought into the open air, men work amongst it without any apparent injury to their health. The only safe way to utilize sewage is, however, by a daily application of it to land whilst it is comparatively fresh, as at Bedford, Aldershot, Carlisle, Doncaster, Chorley in Lancashire, Leamington, Rugby, and other places where sewage irrigation has been established and the sewers transmit in a continuous stream the daily volume.

Receiving sewage in tanks to abstract the solids will add to the impurity and offensiveness of the fluid if there is any lengthened retention, or if the tanks are not rigidly cleansed at short intervals, so as to remove any of the leaven of putridity from the surfaces. All sewage-tanks should be simple in form and construction, the material should be either of a vitreous character on the surfaces, such as glazed bricks, or of Portland concrete; no sewage-tank should be arched or vaulted over. There may be an open-sided shed louvered at the ridge, and the area of land occupied by both yard and tanks should be fenced in.

The sludge separated from sewage contains from 80 to 90 per cent. of water, and if deposited on the surface in this state it will not dry in any reasonable length of time, but will skin over and remain wet. Artificial drying is not practicable on account of the cost. Mixing with dry ashes and street-sweepings appears to answer best.

Unventilated Foul Sewers and Sewage Tanks dangerous.

Foul sewers and foul vaulted sewage-tanks, if unventilated, will contain carbonic acid gas, and will give off sulphuretted hydrogen, both of these gases being generated from decaying vegetable and animal matters. A complete and perfect disinfection of sewage and sewage deposit by the addition of any known materials, solid or fluid, would be so costly as to be impracticable, and the materials so disinfected would have no equivalent increase in commercial value. To completely disinfect one cubic foot of sewage-sludge and excreta would cost, in the materials, about 1*s.* or 27*s.* per ton.*

Carelessly Cleansing Sewers during Periods of Sickness dangerous.

Cleansing the putrid refuse from unventilated sewers or from covered tanks is a dangerous process, men having fallen dead during the operation. A sewer or tank full of refuse is dangerous, but when first emptied, and for some time after, there may be the greatest danger, as the sides and bottom are coated with putrid leaven and the increased cubic space within is filled by highly concentrated gases and effluvium, consisting partly of floating particles suspended in the air. When there are foul sewers and cesspools where disease, such as typhus or typhoid, breaks out, it is then most dangerous to attempt cleansing unless the sick are first removed and the greatest precautions in disinfecting are taken.

* Note.—See Appendix No. 5, page 77.

Details of the Modes of dealing with Sewage.

The application of town sewage to land is shown in this report to be the cheapest mode of disposing of it. The first cost of purchasing land for a sewage farm, of preparing this land to receive and filter sewage, and of constructing the necessary works and machinery, may require a rate in aid during the term allowed for repayment of the capital; but in most cases; where the sewage can be applied at a reasonable cost, by gravitation, so far as our investigations have been extended, there will be an available income from the farm at the termination of the temporary debt.

Sewage irrigation should in all cases be practised where there is land to be obtained, and the prospect of a balance of income in its favour, as sewage-grown grass is wholesome, and when used for dairy-cow feeding produces good milk, and affords employment to a large number of labourers.

The application of sewage to land need not in any case produce a swamp, nor generate malaria, as the volume of sewage applied at any period should be delivered in a thin film, such as the land can absorb at once; that is, within a few hours of its delivery.

Sewage should not in any case drench the land to which it is applied as is usual with water irrigations, where extensive areas are laid under water for several days at a time. The volume of sewage from any town being known, the sewage-farm should be from 10 to 15 per cent. greater than the area required for one week, and no more than one tenth of the area of a sewage-farm should ever be under sewage at one time.

A wet season is not, as a rule, detrimental to a sewage-farm. In a wet season the value of sewage grown grass is, however, reduced in value because there is more difficulty in removing crops from the ground.

Rent of Land used for Sewage Irrigation excessive.

At Croydon some 515 acres of land are under irrigation, the population being about 56,000. This is at a rate of near 10 acres for each 1,000; or about one acre to 100. The land in use had an average rental of 26*s.* to 30*s.* before the Croydon Local Board of Health required it; the rent now paid averages 10*l.* per acre per annum.*

Examples of Sewage Irrigation.

Analyses of crude and purified sewage, at the places named, are given in Appendix No. 5, pages Nos. 77–102:—

Edinburgh, Craigentinny Meadows.	Banbury.
Barking, Lodge Farm.	Warwick.
Aldershot Farm.	Worthing.
Carlisle.	Norwood.
Penrith.	Croydon.
Rugby.	Woking.

* Note.—A sewage-farm will not bear a rent of 10*l.* per acre. About half this sum is as much as should be paid if the income is to cover the expenditure.

Analyses of town sewage having been so recently made for the special purpose of informing Parliament, that we did not consider it necessary to again incur the costs of special analyses being made for our Report; but we have deemed it proper to have samples of the most recent specimens of manipulated sewage-sludge analysed, and the results will be found in the Report by Dr. A. Voelcker, F.R.S., pages 40–43, and in Appendices Nos. 1, 2, 3, 4.

A sewage-farm should be so laid out and managed that a sufficient area of land shall be under sewage every day in the year, winter and summer; and as town-sewage is seldom below 40 degrees in temperature, irrigation can be carried on. And if sewage should freeze on the surface of land which is without crop no injury is done, and when thaw sets in absorption takes place.

The mode of laying out a sewage-farm cannot be fully described in this report, but see the maps and diagrams for partial elucidation. As a rule it may be stated that the works should be simple in character that they may be cheap in construction. Good examples may be seen at Doncaster, at Bedford, at Leamington, and at Aldershot.

Permanent sewage-carriers should contain the land and be laid so as to be level, the grade of the land being provided for by vertical steps regulated by stops, overflows, and wash-outs; side-junctions to be provided on the lower sides of the carriers to draw off sewage for distribution over the land. If a permanent sewage-carrier is laid with a fall, it will be impracticable to block the flow at any point and preserve an even surface, as sewage blocked in a sloping channel would flood over the point of stoppage; hence the necessity for level lines at the surface.

Tributary-carriers may be made by a plough, the cross-sectional form and the gradient being suited to the character of the soil; the larger carriers may have a grade of 1 in 400; the smaller or "herring-bone lines" may have a grade of 1 in 300. These temporary carriers will be broken up with the plough at intervals, and be renewed as required.

Crude sewage can be used under certain conditions to warp the land; that is, the sewage with all the sediment it will carry may be passed along the carriers to be incorporated with the soil by being ploughed in, and the water of sewage may in some cases be made to carry an extra weight of silt.

The solids of sewage, as also manure made on the farm at the cattle sheds, may be used on some farms with advantage, as it does not follow that liquid sewage will in all cases supply manure sufficient.

During dry seasons the whole of the water applied in irrigation of free soils is absorbed or evaporated, the drains being absolutely free from any outflow. At all periods evaporation and absorption dispose of a large percentage of the water; and if the land is deep drained and well cultivated, the outflowing water from the drains is free from colour and scent; and if passed into a water-course does not taint the bed of the stream nor produce sewage growth so offensive in sewage polluted streams.

Where the area and surface slope of a sewage farm is favourable, intercepting drains may bring the once filtered sewage to the surface and so allow of a second or a third filtration. In a dry season there will be an advantage in this arrangement. Where the land is marl or clay this mode of irrigation will be specially advantageous, as the main purpose of a sewage-farm is to act as a sewage-filter and purifier, and the more completely this filtering is performed the better will be the results.

Land may be prepared to filter sewage, as suggested by the Rivers Pollution Commissioners. (Mersey and Ribble Basins, 1st Report, pp. 60–70.) Where small areas of land are alone available this mode of purifying sewage will be advantageous. The crude sewage should have suspended solids separated in tanks that the clarified fluid may more readily filter through the least area. A good example of sewage filtering through land on a working scale may be seen at Kendal.

Area of Land required for a Sewage-Farm will depend on Local Conditions.

The area of land required for a sewage-farm will be governed in a great measure by the character of the subsoil, as if it is very porous or otherwise; as also by the volume of sewage and subsoil-water in proportion to the population. At Doncaster, with a sewage-farm of 264 acres and a population of 20,000, the average daily flow of sewage being about 600,000 gallons, 120 acres of land of a light sandy and open character have for three years absorbed the entire sewage, only about five acres at any one time being under sewage, and one acre has occasionally absorbed the entire volume of one day. At Croydon about one acre to each 100 of population has been provided. For a population of 60,000 there are about 15,000 waterclosets in use; or, one to four of the inhabitants. There are the contents of 25 waterclosets in 20 tons of sewage each day; or, about 7,000 tons of sewage per acre per annum.

Small fields enclosed by large fences will be detrimental to sewage farming; land which is open and without inner fences, having a uniform surface and gentle slope to the south, will be most advantageous. Good roads will, of course, as in any other case, be an advantage; but it will neither be desirable nor necessary to construct many roads of a permanent character through and over a sewage-farm, as the land, if well laid out and properly drained, may be carted upon to remove the crops.

Italian Rye-grass the best Crop under Sewage.

Italian-rye-grass is probably in all respects the most advantageous crop to be grown under sewage, as it absorbs the largest volume of sewage, occupies the soil so as to choke down weeds, comes early into the market in spring, continues through the summer and autumn, bearing from five to as many as seven cuttings in the year, and producing from 30 to 50 tons of wholesome grass upon each acre. The area placed under this crop must,

however, have reference to local means of consumption, as the young grass will not keep nor bear long carriage. It is most profitable for feeding milch cows. A dairy and a sewage farm should, therefore, wherever practicable, be associated. In a dry and warm summer good hay may be made, which will be sweet and wholesome.* For full details of experiments with sewage grown grass, meadow and Italian, and for analyses of the milk produced, see the Official Report, Royal Commission appointed to inquire into the best mode of distributing the sewage of towns and applying it to beneficial and profitable uses. See also Appendix No. 7.

A Portion of a Sewage-farm should be deep drained to act as a Land-filter.

A portion of each farm should be specially deep-drained and prepared for land-filtering the sewage during winter or wet weather. When these filters are laid out in raised beds, some roots and vegetables can be cultivated with success, as the sewage generally flows down the channels. But in times of flood and storms the sewage may rise above the beds, so that it appears *oziers*, which would not be damaged by being flooded for days, may be the safest and therefore the most profitable crops to grow upon them.

Experience has proved that each day's sewage may be disposed of throughout the year so as not to cause any nuisance. Land well drained, properly laid out and managed, does not swamp at the surface, neither does it choke in the subsoil, as in fallow-land oxydation goes on betwixt the intervals of irrigation, and at any time the few grains of matter extracted from the sewage-waters are only a homœopathic dose to the land compared with the bulk of soil, six feet in depth. It is a few grains of salt and organic matter extracted from the sewage which remain for the use of the plants, the water evaporating or flowing from the drains. In dry seasons, for weeks at a time, the drains deliver very little water.

Drains and Waterclosets.

Drains must not traverse the basements of houses, but must commence at an outside wall and be fully ventilated. Water-closets must not be within the body of a house, but against an external wall, the soil-pipe being ventilated above the roof, with an open top, so as to ventilate fully, the watercloset room having full and free ventilation at the ceiling. The main sewers must be true in line, having smooth and even gradients, and be fully ventilated. The water supply must be constant and abundant, laid on to each house and to each watercloset; contamination by sewage gas within dwelling-houses will then be practically impossible.

Sewage is the waste-water from towns and the polluted water and liquids from manufactures. Where the privy, cesspit, and cesspool are retained the corrupted fluids from these pass into the

* Note.—July 1876. On the Doncaster sewage-farm 18 acres of Italian rye-grass have been cut (about 9 tons green) and made into hay (about 2½ tons per acre), or some 45 tons of hay from one cutting alone.

sewers. Where waterclosets are used drains and sewers remove the contents at once.

Sewage is injurious in proportion to its age and putridity. Fresh sewage, if removed day by day, does not, in that time, become putrid; and, consequently, is not so injurious to health as putrid sewage is.

In towns completely sewered and drained, and fully supplied with water and waterclosets, there is an unceasing flow along the sewers to the outlet, and the strength of the sewage varies during the day in proportion to the use of water and of waterclosets. The flow is greatest in the morning, at noon, and in the evening. At night the sewers deliver almost pure water, consisting of waste from leaking pipes and taps, with subsoil water.

Where waterclosets are in full use, as in London (about 700,000), in Croydon (15,000), in Leamington (about 8,370), in Harrogate (about 1,620), in Cheltenham (about 8,500), and in like proportion in some other towns, the entire of the polluted fluids, with the effete matter of the watercloset, passes at once to the common outlet. The London sewage is at present wasted into the river Thames; but at Croydon, Leamington, Harrogate, and Cheltenham the sewage is purified by irrigation, in each case producing useful crops of grass and vegetables.

Where towns are situate on the sea or on the estuaries of tidal rivers sewage is wasted, as at Brighton, at Liverpool, at Sunderland, and even at Edinburgh, where the Water of Leith intercepting sewer discharges the sewage from a population of about 100,000 by a cast-iron outlet direct into the Frith of Forth. When sewage shall be wasted in preference to utilising it, must depend upon local conditions. The waste of sewage must not, however, produce a nuisance injurious to health, and this wasting of it certainly ought to be cheaper than using it under any of the precipitating and chemical or irrigating processes at present known.

Clarification of Sewage.

Clarification by deposition in tanks and treatment by chemicals remove detritus and suspended matters from sewage, but, as explained, will not fully purify the fluid. This removal of the solids will, however, be an advantage, as a vast mass of matter liable to choke the bed and banks of a stream or river will be removed, which, when allowed to accumulate, becomes putrid and offensive. The streams in Lancashire and Yorkshire are so fully occupied, and water is of such importance, that the manufacturers must have it, though dirty; steam-boilers being specially constructed to enable steam to be generated from dirty water. The cost of treating sewage in tanks and by chemicals appears to be about 1,500*l.* per annum for each 1,000,000, or 150*l.* for each 100,000 gallons per day. The cost is therefore in round numbers about $\frac{3}{4}$ths of a farthing per ton of the sewage so treated. Any income realised by the sale of the extracted and treated sludge will be in diminution of this cost.

The gross cost of purifying sewage by irrigation is, per ton, at Doncaster $\frac{2\,3}{6\,4}$ of a penny, at Bedford $\frac{5\,1}{6\,4}$ of a penny, at Leamington $\frac{3\,8}{6\,4}$ of a penny, at Cheltenham $\frac{1\,9}{6\,4}$ of a penny, and at Banbury $\frac{4\,8}{6\,4}$ of a penny. These farms may be accepted as fair samples of thus utilising sewage.

The use of sewage in agriculture is comparatively new, and the best mode has not in all cases been practised. We, however, indicate Aldershot, Bedford, Doncaster, Leamington, Wolverhampton, and Wrexham as good examples. At Lemington Lord Warwick leases the sewage to be used upon a portion of his estate, and at Aldershot, Wrexham, and at Doncaster the sewage and the land are leased, and are worked independently by gentlemen of intelligence, who make such experiments as they think proper and vary their modes of culture as best suits the sewage, the land, and the crops to be grown, There is also the incentive to make the most of the land, which is not always the case where a farm is managed through the intervention of a committee ; we therefore look for a fuller development of sewage farming in this direction ; namely, letting both sewage and land on favourable terms, under restrictions to purify the sewage and cause no nuisance.

Examples of tank precipitation and chemical treatment at Birmingham, Bradford, Coventry, and Leeds, and of the pail system at Rochdale, Halifax, and at other places are described in this Report, Appendix No. 3, pages 52–59. The pneumatic system is described by the authorities of Amsterdam, Appendix No. 4, pages 62–66.

The attempts to economise in town scavenging and sewering by removing human excreta separately has been a failure ; by the dry-earth system, the Goux system, the Rochdale pail system, or by any other of the patented systems, so far as are known to us; the local costs have been largely increased, and the local nuisances also, in proportion to the time of retention of the excreta before removal ; there is also the inconvenience suffered by trespass on the privacy of the household.

Details as to Irrigation by Town Sewage.

As we recommend the application of town sewage to land, we at the same time wish to guard against some extravagant expectations of the agricultural benefits it will confer, which are held and advocated by a few zealous and enthusiastic theorists.

The continuous application of town sewage to all soils is by no means an unalloyed benefit; as in some cases and seasons, and especially upon clay-land, it may be rather injurious than otherwise. Very few crops are actually benefited by the direct application of sewage upon a stiff and retentive soil ; indeed, Italian rye-grass, cabbage, and mangold-wurtzel, seem to be the only farm crops that persistently flourish upon any soils, heavy or light, under continual doses of town sewage.

No growing crop, save natural grass, should be sewaged during

the depth of winter; and for potatoes, turnips, most vegetables, and certainly for all pulse and cereals, the land ought rather to be enriched by frequent irrigation in the preceding season, than treated with sewage when these crops are growing; except in times of great drought, and even then care is requisite. A very limited experience soon teaches us that the purification of a constant flow of sewage, and which is frequently greatest when least wanted on the farm must bring certain difficulties in its train. The cultivation of sewaged land, for instance, requires more than double the amount of manual labour which is usually employed upon arable land, and more horses must be kept than upon an ordinary farm. The amount of capital, even where the produce is sold off as soon as grown, must be greatly in excess of that required for the general ordinary cultivation of the soil; while to properly stock and work a sewage-farm upon which the main produce is consumed, quite five times the usual amount of money will be needed. One of the greatest difficulties is to keep the sewaged land clean, as not only does every seed and the minutest portion of a root-weed grow, but sewage itself often contains the seeds of numerous weeds which have been washed down from the fodder and straw of stables and cowhouses in towns.

There can be no doubt now, after the experience of some years, that the land best adapted for sewage irrigation is a warm friable loam. The only instance in which town sewage irrigation is a decided financial success is that of the Craigentinny Meadows, at Edinburgh. These meadows are, however, in reality for the most part only a deposit of sea sand, washed and blown from the adjoining estuary, and the main produce grown is nothing more nor less than luxuriant couch-grass. The enormous amount of coarse forage which is produced from such a naturally sterile soil shows the fertilizing properties of town-sewage, and also points still more distinctly to the fact that a sewage-farm should consist of land through which the sewage can readily filter. It is strange that although deluges of crude town-sewage have been poured upon portions of these Craigentinny Meadows for 200 years, the discoloration of the sandy soil only extends a few inches below the surface, and that at the depth of a foot the sand appears as bright and clean as that upon the adjoining sea shore.

It has been contended that if more land is allowed for a given volume of sewage, clay soils, when properly drained, will be equally adapted for town sewage irrigation. No doubt, if similar volumes of sewage are filtered slowly through a large area of well-drained clay, and quickly through a small area of sand or gravel, a more thorough absorption of the manurial elements from the sewage will be made by the clay than by the porous soils. But clay lands are naturally cold, they dislike wet, and will be at the best only poor filter-beds; and when sodden with rain-water the added sewage is apt to pond on the surface rather than to soak gradually into the already heavily wetted soil. After heavy dressings of sewage in parching weather

the surface of clay lands may be so baked and case-hardened as considerably to retard the growth of any plant; and if there is no crop upon the ground the land becomes solidified, and may then be seen coated with a nasty greasy film that is almost impervious to water; or, at other times, the clay cracks so that the crude-sewage passes in small streams directly into the under drains without being even clarified.

This brings us to consider the various methods of underdraining as practised at different sewage-farms we have inspected. In one instance we found that common farm underdrains which had been laid in a retentive soil were being taken up, as the crude sewage too readily found access to them, and flowed out unpurified. Upon another sewage-farm some stiff clay land which had been recently drained 6 feet deep was so cracked by heat and drought, that the sewage flowed from the surface into the drains without effecting any practical irrigation; and, although intercepted and brought to the top again, the sewage as rapidly disappeared, and at the land drains outlet the effluent was hardly distinguishable in colour and smell from that of the sewage when first applied to the land.

There seems no doubt that even the lightest soils should have a few deep underdrains, as at Doncaster, and Heathcote farm, Warwick, so as to prevent the sewage-water from lodging in the subsoil. All land of medium staple should be thoroughly underdrained, and clays require the drains to be multiplied, so that the interval between them shall not be more than 15 feet; and care should be taken that the drains are so formed that no sewage-water can flow vertically into them. To prevent this, upon the top of the drain-pipes, a foot of the most retentive portion of the soil should be damped or puddled, and tightly rammed down, so that the sewage-water after percolating through the subsoil shall flow horizontally into the drains, and not rush into the drain-pipes through the loose mould or cracked clay directly from the surface.

As already observed, the chief produce of a large sewage-farm, which is to earn the most money, must be Italian rye-grass; because it is a plant which luxuriates in moisture, and feeds with singular avidity upon all kinds of liquid-manure: and the quantity of such liquid-manure given need only be limited by the means at hand for its ready disposal. But the demand for cut grass is so variable, that this is not a very easy task. Rye-grass, even when heavily sewaged, grows most rapidly in wet weather: consequently when there is much rain, a greater crop is produced, when it is most difficult to deal with; and, as there is at such times a more plentiful supply of similar green food on other farms in the district, the demand for the rye-grass of the sewage-farm is not so extensive. In a damp season it is next to impossible to make sewage-grown grass into hay, as the soil is sodden with rain-water and sewage, and the young undergrowth of grass so soon springs up that the land must be cleared of the cut grass to enable the next crop to grow; and any removal of the cut grass

to other ground for the purpose of making hay, even if a suitable site is conveniently situated, will be very costly. It therefore appears to us that upon an extensive sewage-farm, where a constant demand for all the rye-grass grown cannot be depended on, a machine for making hay by artificial means should be provided.

Drying heavy crops of sewage-grown grass by artificial heat must; however, be a slow, costly, and tiresome process, and should never be resorted to unless necessity compelled this form of dealing with it, and when it appears to be the only way to prevent the total loss of the crop during continuous wet weather. We believe the best machine for the purpose is one which is the invention of Mr. W. A. Gibbs, of Gilwell Park, Essex, to whom the gold medal of the Society of Arts was awarded a few years ago for the ingenious apparatus which bears his name.

The length of time which a plant of irrigated Italian rye-grass lasts varies considerably. On some farms it has been ploughed up after one year's cropping. On other farms the practice has been to keep it down so long as there is a good plant, and it can be kept free from weeds. By fresh seed being sown among the old plants, Italian rye-grass thus treated, has lasted seven or eight years. Its more usual duration is, however, from two to three years, and as there seems to be a common belief that this plant can only produce a certain weight of grass, it may follow that the quicker the growth the more readily the plant will be exhausted.

It was a matter of pleasure and some surprise to us to find how town sewage benefited two such distinctly different forage plants as Italian rye-grass and lucerne. The latter, it is well known, grows with one deep tap-root, while the rye-grass has a dense mass of fibrous rootlets, which extend upon and over the surface of the land. At Paris the favourite green crop for sewage appeared to be lucerne, which at the time of our inspection seemed to flourish remarkably well under sewage irrigation, and to produce heavy crops of the most valuable provender. The gravelly soil and the warm climate of the district no doubt are particularly adapted for sewage irrigation, and this may be the reason why a direct application of sewage to the growth of vegetables seems to answer better than with us. The culture of Italian rye-grass has only recently been introduced on the Paris sewage-farm, but its success is so marked that it may possibly take the place of lucerne as the staple green crop.

English farmers have by some been considered over cautious in not embarking their capital in the costly cultivation of sewage-farms, but on our inspection of the Paris farms it appeared much more strange to us that so many French cultivators, whose little patches of land intersect the Paris sewage-farm, had not all availed themselves of the *free use* of the sewage. Many, no doubt, have done so, but it was difficult to comprehend how some of the farmers preferred to grow their miserably small crops when the adjoining

land upon which the sewage flowed was producing the most abundant yield.

It may be quite true that town sewage contains all the manure that most plants require, but as these elements of fertility are dispersed through a volume of water many times greater than any crop can absorb, and certainly much larger than it naturally requires, it follows that the manure is not presented to the plant in the most acceptable form. We have been also assured by a gentleman of vast experience that the long continued application of sewage to the same land fails to produce the like beneficial effect as when it was first used. It, therefore, appears most desirable that the application of sewage should occasionally be supplemented with some solid manure. Cows are the most suitable and best paying animals for consuming the produce and manufacturing manure upon a sewage-farm, and cows should always form the chief portion of its live stock. The successful management of animals, and the proper cultivation of crops under ordinary circumstances, require a fair amount of intelligence and experience; but successfully to carry out all the details of these matters upon a sewage-farm, where there is so little to guide the practical farmer, and so much to confound his past experience and upset his previous calculations, is indeed a hard task. And as most sewage-farms are at present under the control of ever-changing town councils and local boards whose members must as a rule be ignorant of practical agriculture, and whose theories upon the subject may be wild and visionary—is it surprising that such poor returns have hitherto resulted from the application of town-sewage to the growth of crops?

Disappointment has therefore been expressed at the poor financial results of sewage-farms. Agriculture is never a specially lucrative business, and during the last few years it is probable that strictly accurate accounts would prove that very little profit has been derived from the ordinary cultivation of arable land. Farms to which town-sewage is applied have invariably many unfavourable circumstances to contend with. The rent, except where the local authority has land of its own, is certain to be extravagant; the application of sewage is often too costly; the management is frequently changeable and faulty, and the prejudice against the produce of the farm is, in some districts, obstinate and widespread. But where a fair rent is charged for suitable land, the sewage is cheaply and regularly delivered, and a good market is close at hand, there is no reason to doubt that the return for capital judiciously expended upon sewage-farms will produce a higher rate of interest than the money invested by the majority of the tillage farmers throughout the country.

ABSTRACTS

From separate Reports. See Appendices Nos. 1, 2, 3.

The relative costs of sewage irrigation, where the sewage gravitates to the farms, are shown in the abstracts from the reports on Edinburgh, Blackburn, Cheltenham, Chorley (Lancashire), Harrogate, Merthyr-Tydfil, Tunbridge-Wells, Rugby, Wolverhampton, West Derby, and Wrexham. The relative cost of sewage irrigation, where sewage is pumped, is shown in abstracts from reports on Banbury, Bedford, Doncaster, Leamington, and Warwick, whilst the cost of land filtration and irrigation is shown as practised at Kendal, and the cost of the precipitating chemical and mechanical processes are shown in the abstracts from the reports on Kendal, Birmingham, Bolton, Bradford, Coventry, Leeds, Halifax, and Rochdale.

The abstracts contain statistics to which attention should be given. The returns are not however perfect, as the local works are not yet complete, and we could not, in all cases, obtain accurate returns of the costs of scavenging; the weight of refuse removed; or, the cost of removal:—

COST OF DEALING WITH SEWAGE BY IRRIGATION.

Banbury.

Population (about)	12,000
Rateable value	£34,104
Houses	3,485
Waterclosets	2,485

Expenses incurred to dispose of the Sewage.

Outlet works, tanks, and pumping main	£5,500

The Yearly Cost of disposing of the Sewage.

Capital 5,500*l.* at 6* per cent. to repay principal and interest. Yearly instalment	£330
Cost of pumping sewage, including rent and working expenses of farm	1,281
	1,611
Less produce of farm	1,451
	£160

The mean daily flow of the sewage is about 320,000 gallons = 1,429 tons, or 521,585 tons yearly. The annual cost to the Local Board in disposing of the sewage is 1,611*l.*, or at the rate of $\frac{48}{64}$ths of a penny per ton; they

* Money is advanced by the Public Works Loan Commissioners at 3½ per cent., which, to be repaid in 30 years, amounts to 5*l.* 8*s.* 9*d.* per cent. Six per cent. is however here used for the sake of uniformity and the purpose of comparison to cover incidentals and depreciation.

Local Boards do not necessarily borrow from the Public Works Loan Commissioners, neither do they, in all cases, repay the debt in 30 years, as the Local Government Act, 1875, provides for a term not exceeding 60 years, and this lengthened term, when accepted, will lower the rate of interest, but the cost of maintenance cannot be ascertained with accuracy.

receive for the produce 1,451*l.*, an amount equal to $\frac{44}{64}$ths of a penny per ton of sewage, and consequently lose 160*l.*, or about $\frac{4}{64}$ths of a penny per ton, or at the rate of 3*d.* per head of the population, or about 1*d.* in the pound on the rateable value of the town.

The capital, 5,500*l.*, will be paid off, and then the annual payment of 330*l.* will cease, and the rates will thus be relieved to the extent of about $2\frac{1}{4}d.$ in the pound on the present rateable value.

The volume of sewage is at a rate of 27 gallons per head of the population, or about eight persons to every ton of sewage.

Bedford.

Population (about)	18,000
Rateable value	£65,000
Houses	3,500
Waterclosets	3,000

Capital Expended on Works to dispose of the Sewage.

Outlet works, pumping station, and laying out farm - £9,200

The Yearly Cost of disposing of the Sewage.

	£	s.	d.
Capital 9,200*l.* at 6 per cent. to be repaid in yearly instalments	552	0	0
Paid for labour, tradesmen bills, coals, &c. in working sewage farm, including amount of rent, rates and taxes, and also cost of seed	3,280	7	8
	3,832	7	8
Less amount received for sale of stock and crops	3,461	6	0
	£371	1	8

The daily mean flow of sewage is about 700,000 gallons = 3,125 tons, or 1,140,625 tons yearly.

The annual cost to the Corporation in disposing of the sewage is 3,832*l.* 7*s.* 8*d.*, or at a rate of $\frac{5}{64}$ of a penny per ton; they receive for the produce 3,461*l.* 6*s.*, an amount equal to $\frac{46}{64}$ of a penny per ton of sewage, and consequently lose 371*l.* 1*s.* 8*d.*, or about $\frac{5}{64}$ of a penny per ton; or at the rate of $4\frac{3}{4}d.$ per head of the population, or 1*d.* in the pound on the rateable value of the borough.

The volume of sewage is at the rate of 39 gallons per head of the population, or about six persons to every ton of sewage.

The capital 9,200*l.* will be paid off when the rates will be relieved to the extent of about 2*d.* in the pound on the present rateable value.

Blackburn.

Population (about)	90,000
Rateable value	£235,127
Houses	16,700
Waterclosets	730
Privies and middens	10,574
Privies on "pail" system	2,690
Ashpits	5,287

The yearly cost of cleansing the privies on both systems is	£5,641
Amount received for the refuse	1,806
Consequent loss on removal	£3,835

Or at a rate of 10¼*d.* per head of the population, or about 3¾*d.* in the pound on the rateable value of the borough.

CAPITAL EXPENDED in DISPOSING of the SEWAGE.

Damages and cost in Chancery suit, and action at law	£12,000
Cost of obtaining private Act	6,500
Costs of outfall sewer, and laying out sewage-farm at Pleasington	11,600
Purchase of land at Samlesbury, including expenses of arbitration and easements	*69,500
Cost of laying out this farm for sewage irrigation	*7,650
	£107,250

N.B.—* The sums marked thus are for land and works which have not come into profitable use at present.

The YEARLY COST of DISPOSING of the SEWAGE.

Capital 107,250*l.* at 6 per cent., to repay principal and interest. Yearly instalment	£6,435
Rent of farm at Pleasington	484
Working expenses of farm	6,523
	13,442
Less sale of produce	5,781
	£7,661

The mean daily flow of the sewage is 1,500,000 gallons = 6,696 tons, or 2,444,040 tons yearly. The annual cost to the Town Council in disposing of the sewage is 13,442*l.*, or at a rate of $\frac{5}{6\,4}$ths per ton; they receive for it in sale of produce 5,781*l.*, an amount equal to $\frac{3\,6}{6\,4}$ths of a penny per ton of sewage, and consequently lose 7,661*l.*, an amount equal to about $\frac{4\,5}{6\,4}$ths of a penny per ton, or at a rate of 1*s.* 8¼*d.* per head of population.

The yearly loss in cleansing privies	£3,835
„ „ disposing of the sewage	7,661
	£11,496

or at a rate of 2*s.* 6½*d.* per head of population, or 11½*d.* in the pound on the rateable value of the borough.

The borrowed capital amounting to 107,250*l.*, and which involves an annual payment of 6,435*l.*, will cease when the terms have been accomplished, so that the rates will be relieved (at the existing rateable value) to the extent of about 6½*d.* in the pound.

The volume of sewage is at the rate of 17 gallons per head of the population, or 14 persons to every ton of sewage.

CHELTENHAM.

Population (about)	45,000
Rateable value	£217,849
Houses	8,725
Waterclosets (about)	8,500
Quantity of refuse removed yearly from ashpits (cubic yards)	3,234
Cost of removing ashes yearly	£324

or at the rate of 2*s.* per cubic yard or about 1¾*d.* per head of population.

CAPITAL EXPENDED for DISPOSING of the SEWAGE.

Purchase of farm and cost of construction of works for sewage utilization	£18,000

The YEARLY COST of DISPOSING of the SEWAGE.

Capital 18,000*l.* at 6 per cent. to repay principal and interest in 30 years - - Yearly instalment		£1,080
Cost of applying sewage to farm - - -		150
Rates and taxes - - - - -		50
Cost of cleaning out sewage tanks - - -		296
		£1,576
Less rent obtained for the farm - -	£800	
Amount for sewage applied to land adjoining the sewage carriers - - - -	156	
Amount received for sludge mixed with house-ash - - - - - -	348	
		£1,304
Consequent loss -		£272

The daily mean flow of the sewage is 1,250,000 = 5,580 tons or 2,036,700 tons yearly. The annual cost to the Improvement Commissioners in disposing of the sewage is 1,576*l.*, or at the rate of $\frac{19}{64}$ths of a penny per ton; they receive for it 1,304*l.*, an amount equal to $\frac{16}{64}$ths of a penny per ton of sewage, and consequently lose 272*l.* or about $\frac{3}{64}$ths of a penny per ton, or at a rate of 1¼*d.* per head of the population.

The yearly loss in cleansing ashpits - - -	£324
„ „ in disposing of the sewage - -	272
	£596

or at a rate of 3¼ per head of the population or about three-fourths of a penny in the £ on the rateable value of the district.

The volume of sewage is at the rate of 28 gallons per head of the population, or 8 persons contribute to every ton of sewage.

The capital of 18,000*l.* will be paid off and then the annual payment of 1,080*l.* will cease, and the rates will be relieved to the extent of about 1¼*d.* in the pound on the present rateable value.

CHORLEY (Lancashire).

Population (about) - - - - -	20,000
Rateable value - - - - - -	£54,407
Houses - - - - - - -	4,000
Waterclosets - - - - - -	200
Privies and middens - - - - -	1,600
Privies "pail" system (about) - - - -	700
The yearly cost of cleansing the privies on both systems is - - - - - - -	£709
Amount received for the refuse - - - -	186
Consequent loss on removal - - - -	£523

or at a rate of 6¼*d.* per head of the population or about 2¼*d.* in the pound on the rateable value.

EXPENSES incurred in DISPOSING of the SEWAGE.

Purchase of farm at Common Bank - - -	£6,450
Outfall sewer, laying out farm and erecting farm-buildings - - - - - -	4,800
Purchase and laying out of part of Kingsley's farm -	5,300
	£16,550

The Yearly Cost of disposing of the Sewage.

Capital 16,550*l.* at 6 per cent. to repay principal and interest - - - Yearly instalment		£993
The working expenses of the farm - - -		927
		£1,920
Less amount for produce sold - - -	847	
„ rent received for part of Kingsley's farm with sewage - - - -	90	
		£937
		£983

The daily mean flow of the sewage is about 500,000 gallons = 2,232 tons or 814,680 tons yearly. The annual cost to the Improvement Commissioners in disposing of the sewage is 1,920*l.* or at the rate of $\frac{2}{3}\frac{2}{4}$ths per ton; they receive for the produce of the farm, 937*l.*, an amount equal to about $\frac{1}{6}\frac{5}{4}$ths per ton of sewage, and consequently lose 983*l.* or about $\frac{1}{6}\frac{7}{4}$ths per ton, or at a rate of 1*s.* per head of the population.

The yearly loss on cleansing privies - - -	£523
„ „ in disposing of the sewage - -	983
	£1,506

or at a rate of about 1*s.* 6*d.* per head of the population, or about 7*d.* in the pound on the rateable value of the district.

The volume of sewage is at a rate of 25 gallons per head of the population, or about nine persons contribute to every ton of sewage.

The capital 16,550*l.* will be paid off and then the annual payment of 993*l.* will cease, when the rates will be relieved to the extent of about 4¼*d.* in the pound on the present rateable value.

Doncaster.

Population (about) - - - - -	20,000
Rateable value - - - - -	£68,721
Houses - - - - - -	4,300
Waterclosets - - - - -	Not known.
Privies - - - - - -	3,078
Quantity of refuse removed from privies yearly (tons) -	4,400

Cost of cleansing privies yearly, or at the rate of 2*s.* 5½*d.* per ton - - - -	£539	
Amount received for refuse - - -	310	
Consequent loss on removal - - -	229	
Or at the rate of 1*s.* 0½*d.* per ton, or 2½*d.* per head of the population, or about 1*d.* in the pound on the ratable value of the borough.		

Expenses incurred to Dispose of the Sewage.

Outfall works, including pumping-station, engines, pumps, pumping-main, and laying out farm* -	£20,000

The Yearly Cost of disposing of the Sewage.

Capital 20,000*l.*, taken at 6 per cent., to repay principal and interest. Yearly instalment - - -		£1,200
Annual cost of pumping sewage to farm - -		300
		1,500
Less improved rent for farm - - - -		470
		1,030

* The land is part of a much larger estate which is the property of the corporation.

The daily mean flow of the sewage is about 600,000 gallons = 2,678 tons, or 977,470 tons yearly. This is pumped to a height of 52 feet. The gross annual cost to the Town Council in disposing of the sewage is 1,500*l.*, or at a rate of about $\frac{23}{64}$ths of a penny per ton; they receive for it (*i.e.*, improved rent of farm) 470*l.*, an amount equal to $\frac{7}{64}$ths of a penny per ton of sewage, and consequently lose 1,030*l.* or $\frac{16}{64}$ths of a penny per ton, or at a rate of 1*s.* 0¼*d.* per head of the population, or 3½*d.* in the pound on the rateable value.

The yearly loss in cleansing privies - - - -	£229
„ „ disposing of the sewage - -	1,030
Total - - - - -	£1,259

Or at the rate of 1*s.* 2¾*d.* per head of the population, or 4½*d.* in the pound on the rateable value of the borough.

The volume of sewage is at a rate of 30 gallons per head of the population, or about eight persons contribute to every ton of sewage.

The capital of 29,000*l.* will be paid off and then the annual payments of 1,740*l.* will cease, and the rates will be relieved to the extent of about 4¼*d.* in the pound on the present rateable value.

HARROGATE.

Population (average) - - - - -	12,000
Rateable value - - - - - -	£50,000
Houses - - - - - -	1,500
Waterclosets - - - - - -	1,620

EXPENSES incurred to DISPOSE of the SEWAGE.

Outlet works, and laying out 47 acres of land at Jenny Plain - - - - - -	£1,150
Purchase of Knox Bleachfields - - -	2,200
Purchase of land at Wetherby Lane - - -	1,000
Outlet works, and laying out 13½ acres of land at Wetherby Lane - - - - -	3,484
Estimated cost of laying out farm of 247 acres -	3,216
Damages and costs in Chancery suit (about) - -	9,500
Total - - -	20,550

The YEARLY COST for DISPOSING of SEWAGE.

Capital 20,550*l.* at 6 per cent. to be repaid with interest. Yearly instalment - - -		£1,233 0 0	
Rent of farm of 247 acres - - - -		300 0 0	
Rent and expenses of treating the sewage on the 47 acres - - - - -		282 10 5	
		£1,815 10 5	
Less sale of produce - -	£569 13 1		
Rent of land with sewage at Wetherby Lane - - - -	52 0 0		
		621 13 1	
		£1,193 17 4	

The daily mean flow of the sewage is about 210,000 gallons, equal to 937½ tons, or about 342,187 tons yearly.

The annnal cost to the Commissioners in disposing of the sewage is 1,815*l.* 10*s.* 5*d.*, or at the rate of $\frac{81}{64}$ths per ton; they receive for the produce 621*l.* 13*s.* 1*d.*, an amount equal to $\frac{28}{64}$ths of a penny per ton of sewage, and consequently lose 1,193*l.* 17*s.* 4*d.*, or about $\frac{53}{64}$ths of a penny per ton, or at the rate of 1*s.* 11¾*d.* per head of the population, or about 5¾*d.* in the pound on the rateable value of the town.

The volume of sewage is at the rate of 18 gallons per head of the population, or about 13 persons contribute to every ton of sewage.

The capital 20,550*l.* will be paid off and then the annual payment of 1,233*l.* will cease, and the rates will thus be relieved to the extent of about 6*d.* in the pound on the present rateable value.

LEAMINGTON.

Population (including the districts of Lillington and Milverton)	24,700
Rateable value of the borough of Leamington	£113,400
Inhabited houses	4,500
Waterclosets, average two to a house	8,370
Quantity of refuse from privies removed yearly (cubic yards)	3,000
Cost of cleansing privies yearly, or at the rate of 5*s.* 2¼*d.* per cubic yard, or 7½*d.* per head of the population, or 1½*d.* in the pound in the rateable value	£780
Amount received for refuse	Nil.

CAPITAL EXPENDED ON SEWAGE WORKS.

Outfall works	8,000
Pumping station, including engines and pumps, &c.	16,239
Cleansing river	1,500
Law costs	5,000
Total	£30,739

THE YEARLY COST OF DISPOSING of the SEWAGE.

	£	*s.*	*d.*
Capital 30,739*l.*, at 6 per cent., to repay principal and interest. Yearly instalment	1,844	6	9½
The annual cost of pumping the sewage	1,035	0	0
	2,879	6	9½
Less yearly amount received for the sewage	450	0	0
	£2,429	6	9½

The daily mean flow of the sewage is about 700,000 gallons, equal to 3,125 tons, or about 1,140,625 tons yearly. This sewage is pumped 130 feet high.

The gross annual cost to the Town Council in disposing of the sewage is 2,879*l.* 6*s.* 9½*d.*, or at a rate of $\frac{3.8}{6.4}$ths of a penny per ton. They receive for it 450*l.*, an amount equal to $\frac{6}{6.4}$ths of a penny per ton of sewage, and consequently lose 2,429*l.* 6*s.* 9½*d.* annually, or $\frac{3.2}{6.4}$ths per ton, or at a rate of 1*s.* 11½*d.* per head of the population, or 5*d.* in the pound on the rateable value of the borough.

	s.	*d.*
Yearly loss on cleansing the privies, per head	0	7¼
Yearly cost on disposing of the sewage, per head	1	11½
	2	6¾

The yearly loss by cleansing the privies	£780
„ „ disposing of the sewage	2,430
	£2,210

or about 2*s.* 7*d.* per head of the population, or 6½*d.* in the pound on the rateable value of the borough.

The volume of sewage is at the rate of 28 gallons per head of the population, or about eight persons contribute to every ton of sewage.

The capital, 30,739*l.*, will be paid off and then the annual payment of 1,844*l.* will cease, and the rates will thus be relieved to the extent of about 4*d.* in the pound on the present rateable value.

MERTHYR-TYDFIL.

Population about	55,000
Rateable value	£135,000
Houses	10,778
Waterclosets	8,000
Privies	2,800

The privies are cleansed at the expense of the occupiers of the houses to which they belong.

CAPITAL EXPENDED on WORKS to DISPOSE of the SEWAGE.

Outfall sewer from Troedyrhiew to Ynyscadudug	£16,003
Building subsidence tanks	388
Laying out filters and land for irrigation, including drainage and carriers, at Troedyrhiew	6,015
Purchase and laying out, draining, and fencing common land at Navigation	4,365
Purchase and laying out land at Ynyscadudug	14,387
Purchase of Tyrybout estate	3,002
Purchase of Park Newydd estate	9,170
Total	£53,330

The YEARLY COST for DISPOSING of the SEWAGE.

Capital, 53,330*l.* at 6 per cent., to repay principal and interest. Yearly instalment	£3,200
Cost of distributing the sewage, including working expenses of farm	2,392
Rent of land taken on lease	298
	5,890
Less produce of the farm	1,623
	£4,267

The mean daily flow of the sewage is 1,200,000 gallons = 5,357 tons or 1,955,305 tons yearly. The annual cost to the Local Board in disposing of the sewage is 5,890*l.*, or at a rate of about $\frac{46}{64}$ths of a penny per ton. They receive for the produce 1,623*l.*, an amount equal to about $\frac{12}{64}$ths of a penny per ton of sewage, and consequently lose 4,267*l.*, or about $\frac{34}{64}$ths of a penny per ton, or at the rate of about 1*s.* 6½*d.* per head of the population, or about 7½*d.* in the pound on the rateable value of the district.

The volume of sewage is at the rate of 22 gallons per head of the population, or about 10 persons contribute to every ton of sewage.

The capital of 53,330*l.* will be paid off and then the annual payment of 3,199*l.* will cease, and the rates will be relieved to the extent of about 5¾*d.* in the pound on the present rateable value.

RUGBY.

Population (about)	8,400
Rateable value	£45,000
Houses	1,700
Waterclosets	1,400

CAPITAL EXPENDED on WORKS for DISPOSING of the SEWAGE.

Outlet works and tanks and laying out farm	£5,800

The Yearly Cost of disposing of the Sewage.

Capital 5,800*l.* at 6 per cent., to be repaid with interest.			
Yearly instalment - - - -		£348	0 0
Rent of 65 acres of land - - - -		290	0 0
Rent of 13 acres of land - - - -		54	0 0
	£	692	0 0
Less rent of land sublet with the sewage	- 350		
	79		
		429	0 0
		£263	0 0

The mean daily flow of the sewage is about 400,000 gallons = 1,785 tons, or 651,525 tons yearly. The annual cost to the Local Board of Health in disposing of the sewage is 692*l.*, or at a rate of $\frac{17}{24}$ths of a penny per ton; they receive an improved rent for the sewage farm, 429*l.*, an amount equal to about $\frac{11}{24}$ths of a penny per ton of sewage per year, and consequently lose 263*l.*, or about $\frac{6}{24}$ths of a penny per ton, or at a rate of $7\frac{1}{2}d.$ per head of the population, or about $1\frac{1}{2}d.$ in the pound on the rateable value of the district.

The volume of sewage is at the rate of 48 gallons per head of population, or about five persons contribute to every ton of sewage.

The capital 5,800*l.* will be paid off, and then the annual payment of 348*l.* will cease, and the rates will thus be relieved to the extent of about 2*d.* in the pound on the present rateable value.

Tunbridge-Wells.

Population (about) - - - - -	23,000
Rateable value - - - -	£142,914
Houses - - - - - -	5,750
Waterclosets - - - - - -	5,635

Capital Expended on Works to dispose of the Sewage.

Purchase of farms, law costs, arbitration expenses, and compensation to tenants and cost of laying out farms to receive the sewage -	£87,243	0 0
Cost of cleaning out Summer Hill Lake -	744	17 8
Costs of the Chancery suit - - -	3,000	0 0
	£90,987	17 8

The Yearly Cost of disposing of the Sewage.

Capital 90,988*l.* borrowed at 6 per cent., to be repaid with interest. Yearly instalment -	£5,459	5 0
Cost of disposing of the sewage, including working expenses of both farms - - -	8,199	0 0
	£13,658	5 0
Less produce of both farms - - -	7,671	0 0
	£5,987	5 0

The mean daily flow of the sewage over both farms is 650,000 gallons=2,902 tons, or 1,059,230 tons yearly. The annual cost to the Local Board in disposing of the sewage is 13,659*l.*, or at the rate of 3*d.* per ton; they receive for the produce 7,671*l.*, an amount equal to $1\frac{3}{4}d.$ per ton of sewage, and consequently lose 5,988*l.*, or about $1\frac{1}{4}d.$ per ton, or at the rate of 5*s.* $2\frac{1}{4}d.$ per head of the population, or about 10*d.* in the pound on the rateable value of the township.

The volume of sewage is at the rate of 28 gallons per head of the population, or eight persons contribute to every ton of sewage.

The capital 90,988*l.* will be paid off, and then the annual payment of 5,459*l.* will cease, and the rates will thus be relieved to the extent of about 8½*d.* in the pound on the present rateable value.

Warwick.

Population (about)	11,000
Rateable value	£43,339
Houses	2,400
Waterclosets	2,000

Capital expended to dispose of the Sewage.

Outlet works, including pumping station, engines, pumping main, and laying out farm	£10,084 18 1

The Yearly Cost of disposing of the Sewage.

Capital 10,084*l.* 18*s.* 1*d.* at 6 per cent., to be repaid with interest. Yearly instalment	£604 18 4½
Cost of pumping sewage	572 11 6
	£1,177 9 10½

The mean daily flow of sewage is about 700,000 gallons = 3,125 tons, or 1,140,625 tons yearly. The annual cost to the Corporation of Warwick in disposing of the sewage has been 1,177*l.* 9*s.* 10½*d.*, or at the rate of three-eighths of a penny per ton, and as they do not receive any profit rent for the farm which they have sublet, they consequently lose the whole of that amount, or about 2*s.* 1½*d.* per head of the population, or 6½*d.* in the pound on the rateable value of the borough.

The volume of sewage is at a rate of 64 gallons per head of the population, or about four persons contribute to every ton of sewage.

The capital 10,085*l.* will be paid off, when the annual payment of 605*l.* will cease, and the rates will thus be relieved to the extent of about 3¼*d.* in the pound on the rateable value.

Wolverhampton.

Population (about)	71,000
Rateable value	£210,000
Houses	14,000
Waterclosets	750
Privies (about)	5,000
Quantity of refuse removed from the privies (yearly)	36,000 tons.
Cost of cleansing the privies (yearly)	£3,200

Or at a rate of 1*s.* 9¼*d.* per ton.

Amount received for the refuse	1,600
Consequent loss on removal	£1,600

Or at a rate of 10¾*d.* per ton, or near 6*d.* per head of population.

Capital expended to dispose of the Sewage.

Purchase of farm	£32,000
Cost of reservoirs and other works on farm	6,000
	£38,000

The Yearly Cost for disposing of the Sewage.

Capital 38,000*l.* at 6 per cent. to repay principal and interest.	
Yearly instalment - - - - - -	£2,280
Working expenses of sewage farm - - -	4,451
	6,731
Less receipts for sale of produce and valuation of live and dead stock - - - - - - -	5,097
Annual loss - - - - - - -	£1,634

The mean daily flow of the sewage is 2,500,000 gallons = 11,160 tons, or 4,073,400 tons yearly. The annual cost to the Corporation in disposing of the sewage is 6,731*l.* or at a rate of three-eighths of a penny per ton—they receive for it 5,097*l.*, an amount equal to two-eighths of a penny per ton of sewage, and consequently lose 1,634*l.* or about one-eighth of a penny per ton, or at a rate of 5½*d.* per head of the population, or about 2*d.* in the 1*l.* on the rateable value.

The yearly loss on cleansing privies - - -	£1,600
„ „ in disposing of the sewage - -	1,634
	£3,234

or at a rate of 10¾*d.* per head of the population, or about 3½*d.* in the 1*l.* on the rateable value of the Borough.

The volume of the sewage is at the rate of 35 gallons per head of the population, or about 6 persons contribute to every ton of sewage.

The capital, 38,000*l.*, will be paid off, and then the annual payment of 2,280*l.* will cease, and the rates will thus be relieved to the extent of about 2¾*d.* in the 1*l.* on the present rateable value.

Report of the Wolverhampton Sewerage Committee on the Result of Farming Operations at Barnhurst.*

1st May, 1876.

Appended is a statement of receipts and expenditure in connexion with the farming operations at Barnhurst, for the year ended Lady-day last.

In reviewing the experience of the past year, it may be remarked that although contagious diseases amongst cattle have been prevalent in the district the corporation stock has been entirely free from this form of disease, and that the losses in live stock comprise only one beast from gripes, one sheep and lamb drowned, and three young pigs which died from inflammation.

The past year generally has been unfavourable to successful sewage farming, owing to the extraordinary and frequent heavy falls of rain. Consequent on this the Barnhurst Estate suffered considerably from floods, causing great damage to the grain crops, decreasing the yield, and injuring the quality; still, with all these drawbacks, your Committee have the satisfaction of presenting a balance sheet showing a profit on the year's working of 1,048*l.* 16*s.* 5*d.* equal to 84*s.* 7*d.* per acre on the 248 acres of land under cultivation, or an increase of 52% on last year's experience.

In conclusion, your Committee beg to draw the serious attention of the Council and the public to the great damage sustained to crops through acids being allowed to run into the sewers from manufactories in the Borough. This subject was particularly referred to in the Annual Report of your Committee, in November last, and they cannot now too strongly urge upon the manufacturers the importance of neutralizing the acids and other injurious refuse from their works before allowing them to flow or pass into the drains, or of altogether preventing the same from entering the sewers; and unless some such steps are taken your Committee will reluctantly be compelled to ask the Council to instruct the Town Clerk to take proceedings against offending parties, under the 95th section of the Wolverhampton Improvement Act, 1869.

J. Hawksford, *Chairman.*

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* In this report no notice is taken of the interest on the capital expended, 38,000*l.*, amounting to 2,280*l.* per annum, or 2¾*d.* in the pound on the rateable value of the district.

Barnhurst Farm Account, year ended March 25th, 1876.

Receipts.

1875.	£	s.	d.	£	s.	d.
March 25.						
To Balance, in bailiffs' and other hands				260	13	6
1876.						
March 25.						
To Wheat sold	176	2	6			
„ Barley	181	0	0			
„ Oats	77	2	6			
„ Rye grass	442	14	10			
„ Live stock	1,542	7	8			
„ Hay, straw, &c.	67	15	9			
„ Mangolds, cabbages, &c.	127	15	4			
„ Stock taken into Ley	41	4	0			
„ Miscellaneous receipts, wool, team hire, rents, &c.	186	9	3			
				2,842	11	10
„ Balance due to treasurer and others				1,749	15	0
				£4,853	0	4
Valuation on 25th March 1875	2,465	5	6			
Expenditure as above for the year ended 25th March 1876	2,128	11	11			
	£4,593	17	5			

Expenditure.

1875.	£	s.	d.	£	s.	d.
March 25.						
By Balance due to treasurer and others				2,533	5	6
1876.						
March 25.						
By Labourers' wages	544	14	11			
„ Rates, taxes, and bank interest	146	15	6			
„ Tradesmen's bills	161	3	1			
„ Corn and seeds	106	11	5			
„ Hay, straw, &c.	255	19	0			
„ Manure	50	6	0			
„ Live stock	854	2	0			
„ Turnips and cabbages	9	0	0			
				2,128	11	1
„ Balances in bailiffs' and other hands				191	3	3
				£4,853	0	4
Receipts year ended 25th March 1876				2,842	11	10
Valuation at Lady Day, 1876, as per Mr. T. J. Barnett's valuation				2,800	2	0
				£5,642	13	10
				4,593	17	5
Profit for the year ending Lady day, 1876				£1,048	16	5

Valuation, 25th March 1874.

	£	s.	d.	£	s.	d.
Live Stock	1,266	5	0			
Hay, straw, corn, and off-going tenants share of labour performed	1,051	5	0			
Implements (at 10 per cent. under actual cost)	482	12	0			
				2,800	2	0

John Bryan,
Accountant Clerk.

West Derby.

Population, about		31,400
Annual rateable value		£163,000
Daily volume of sewage about	gallons	750,000
Number of waterclosets about		3,220
Number of ashpit middens		1,630
About two privies to each midden		3,260
Area of sewage farm	acres	207

Total cost of land and works, 63,350*l.*, or at a rate of about 306*l.* per acre.
Sewage, 750,000 gallons equal to 3,344 tons per day, or about 1,220,560 tons per annum.

63,350*l.* capital at 6 per cent.	per annum	£3,800
Annual working expenses		2,335
Total		£6,135
Less total income		3,350
Total annual cost		£2,785

6,135*l.*, equals a rate of		1¼*d.* per ton.
3,350*l.* received, equals		¾*d.* „
2,785*l.*, the annual loss		½*d.* „

There are about 24 gallons of sewage per head, or about nine persons to each ton of sewage.

The annual cost is about 1*s.* 9*d.* per head, and 4¼*d.* in the pound.

17,000 tons of privy midden refuse is removed at an annual cost of 700*l.*, or at a rate of 9¾*d.* per ton. The refuse is the property of the contractor.

Wrexham.

Population	10,000
Houses	2,000
Waterclosets	1,200
Annual rateable value	£32,000

The sewage flows on to the farm by gravitation, the farmer can take in water from the brook, and does so in dry seasons occasionally.

Area of sewage farm, 84 acres. Leased by corporation at 320*l.* a year. Colonel Jones pays 350*l.*, and rents other land, 20 acres, at 40*s.* per acre, or 40*l.* per annum.

104 acres at an annual rental, 390*l.* The tenant only puts sewage on 86 acres.

Dry weather sewage, about 300,000 gallons per day. Wet weather passed to the farm, about 500,000. Flood-waters pass to the river.

Sewage has been applied to the land about six years; Colonel Jones has worked it about four years. Land is open, having a sub-soil of sand and gravel. About five acres are usually under sewage at one time.

Colonel Jones considers that he could with advantage dispose of 500,000 gallons per day all the year round.

Will cultivate about 20 acres of Italian rye-grass. Commenced with three acres, then eight, increased to 17, this next year will be 20. The average cuttings per season have been seven to eight, about 40 tons per season. A single crop has on a portion of the land been 12 tons per acre. The price obtained has been on an average 9*d.* per cwt., or 15*s.* per ton on the ground.

Mangolds, about five acres, 46 tons per acre, sells at 20*s.* per ton. Through the winter the land is dressed with sewage, and some of it warped with the sludge. Ordinarily the sludge is extracted in depositing tanks, four of 180 feet in length, about nine feet wide at top, and three feet deep. Two at a time are in use. The sludge is sold at about 1*s.* 6*d.* per ton.

There is about 1,800 tons of sewage per day, or 657,000 tons per annum.

The corporation main sewerage works cost about 11,080*l.*, this expenditure must not however be charged to the sewage-farm, as it is repaid out of the district rate.

The net profit on the sewage-farm to the corporation is 30*l.*, or about one-ninetieth of a penny per ton, as the value of the sewage to the ratepayers of Wrexham. Colonel Jones considers that the sewage ought to be given.

Colonel Jones has laid down 1,215 lineal yards of 12-inch pipe carriers, at a cost of about 2*s.* 6*d.* per yard, or about 152*l.*

The capital laid out by Colonel Jones is 700*l.*

About 40 head of stock are kept on the farm, milch cows.

Colonel Jones considers that there is more certainty in sewage farming than in ordinary farming, as there is the moisture available at all times. The trouble in wet seasons is in selling and in removing the crop from the land.

There is more produce on sewaged land in wet seasons than in dry seasons; but there is not so good a demand because there is also more grass on unsewaged land, which, in a dry season, is burnt up and consequently is for the time unproductive.

Hafod-y-Wern Farm.

1874–5.—84 acres gross measurement: Rent and taxes, &c. at 5*l.* per acre.

Profit and Loss Account.

1875. Feb. 1.	Dr.	£	s.	d.
	To Balance of sundries and implement account	32	4	0
„	Rent and taxes account	0	9	8
„	Barley crop, couch field* account	15	18	6
„	1873 crops account	3	17	3½
	Interest.			
„	One year on floating capital, 5 per cent on 1,830*l.*	91	10	0
	Payment into Sinking Fund.			
„	5 per cent. on 479*l.*	23	19	0
	Balance profit	276	4	6½
		£444	3	0

1875. Feb. 1.	Cr.	Acres.	£	s.	d.
	By Balance Italian rye-grass account	13	184	16	1
„	Mangolds „	5	46	8	10
„	Filter beds (market garden) account	4	29	17	10
„	Permanent pasture acct.	41	58	8	1
„	Oat crop „	2¼	11	5	6
„	Wheat crop „	6	56	10	11
„	Potato „	2	2	6	4
„	Carrots „	1½	6	17	9
„	Dairy „	—	41	15	7
„	Tank sludge „	1	17	17	6
	Couch field farm, Dr. Side	6		—	
	Total acres in crop	82			
			£444	3	0

1875–6.—104 acres gross measurement.

1876. Feb. 1.	Dr.	£	s.	d.
	To Balance of sundries and implement account	37	4	0
„	Couch field (oats) account*	48	6	1
„	1874 crops' account	19	9	4
	Interest.†	£	s.	d.
	3 months on 1900*l.* at 5 per cent.	23	15	0
	9 months on 1,300*l.*	48	15	0
		72	10	0
	Payment to Sinking Fund.			
„	5 per cent. on 550*l.* for permanent improvements	27	10	0
	† Balance profit	271	18	6½
		£476	17	11½

1875. Feb. 1.	Cr.	Acres.	£	s.	d.
	By Balance Italian rye-grass account	17	275	1	1
„	Mangolds „	5	28	0	5
„	Filter beds (market garden) account	4	17	19	3
„	Permanent pasture	56	50	14	4
„	Oat crop acct.	4	6	12	6
„	Barley crop „	4½	23	15	9
„	"Odd crops" (potatoes, turnips, and carrots)	5	9	2	1
„	Dairy account	—	47	18	6
„	Tank sludge account	—	1	3	1
„	Rent „	—	1	15	0
	Couch field farm „	6		—	
	Total acres in crop	100½			
			£476	17	11½

* This field lies above sewage tanks level, so can get no liquid.

† The main part of dairy stock was handed over to Mr. George Jackson on 15th May 1875 by valuation, and hence the dairyman's profit for nine months, being an unknown quantity, is in addition to this balance. He seems content.

(Signed) Alfred S. Jones, Lieut.-Colonel.

TREATMENT OF SEWAGE BY LAND FILTRATION.

Kendal.

Population, about	13,700
Annual rateable value	£44,600
Houses	2,727
Waterclosets	450
Privies cleansed at the expense of the owners of the houses to which they belong	

Expenses incurred to dispose of the Sewage.

Purchase of sewage farm, repairs, cost of outlet works tanks, preparing filter beds, and levelling land	£18,871

The Yearly Cost of disposing of the Sewage.

Capital, 18,871*l.*, borrowed at 6 per cent., to be repaid with interest in 30 years. Yearly instalment	£1,132
Paid for labour and materials in working sewage farm	110
	£1,242
Less receipts from sale of produce	495
	£747

The mean daily flow of the sewage is about 750,000 gallons, equal to 3,348 tons, or 1,222,098 tons yearly. The annual cost to the Town Council in disposing of the sewage is 1,242*l.* 5*s.* 2½*d.*, or at a rate of three-eighths of a penny per ton. They receive for the produce 495*l.*, an amount equal to one-eighth of a penny per ton of sewage, and consequently lose 747*l.* 5*s.* 2½*d.* or about one-fourth of a penny per ton, or at a rate of 1*s.* 1*d.* per head of the population, or 4*d.* in the pound on the rateable value of the borough.

The volume of sewage is at the rate of 55 gallons per head of the population, or about four persons contribute to every ton of sewage.

The capital, 18,871*l.*, will be paid off, and then the annual payment of 1,132*l.* will cease, and the rates will thus be relieved to the extent of about 6*d.* in the pound on the present rateable value.

PRECIPITATION OF SEWAGE-SLUDGE IN TANKS.

BIRMINGHAM.

Population (about)	350,000
Rateable value	£1,229,844
Houses	83,420
Waterclosets (about)	8,000
Privies, old system	35,000
„ pail system	7,000
Ashpits	25,000
Quantity of refuse removed in 1875 from the privies and ashpits (tons)	128,512
Removing contents	£35,180
Cost of cleansing privies and ashpits yearly, and Amount received for refuse	5,885
Consequent loss on removal, or at the rate of 4*s.* 6¾*d.* per ton, or 1*s.* 8*d.* per head of the population, or 5½*d.* in the pound on the rateable value of the borough	£29,295

EXPENSES incurred to DISPOSE of the SEWAGE.

Purchase of land (farm)	£45,400
Levelling, draining, and laying out	11,250
Outlet works and tanks	58,880
Cost of promoting bill in Parliament	10,644
Compensation to Right Hon. Sir C. B. Adderley, M.P.	6,000
	£132,174

The YEARLY COST of DISPOSING of the SEWAGE.

Capital, 132,174*l.*, at 6 per cent., to repay principal and interest. Yearly instalment			£7,930	8 9½
Part of farm held on lease, yearly rent			855	0 0
Yearly expense of cleansing tanks, removing and digging in 109,500 tons of sludge			12,778	0 0
Yearly cost of General Scott's process			332	0 0
Yearly working expense of farm			2,547	0 0
			£24,442	8 9½
Less amount received for portion of sludge sold	£202	10 0		
Amount received for cement sold (General Scott's process)	179	0 0		
Amount received for sale of farm produce	2,130	0 0	2,511	10 0
			£21,930	18 9½

The daily mean flow of the sewage is about 12,000,000 gallons, = 53,571 tons, or 19,553,415 tons yearly. The annual cost to the Town Council in disposing of the sewage is 24,442*l.* 8*s.* 9½*d.*, or at the rate of about nine

thirty-seconds of a penny per ton. They receive for it 2,511*l.* 10*s.* 0*d.*, an amount equal to about one thirty-seconds of a penny per ton of sewage, and consequently lose 21,930*l.* 18*s.* 9½*d.*, or about one-fourth of a penny per ton, or at the rate of 1*s.* 3*d.* per head of the population.

	s.	*d.*
Loss per head of the population in cleansing privies	1	8
„ „ disposing of sewage	1	3
Total loss	2	11

or 4½*d.* in the pound on the rateable value of the borough.

The yearly loss by cleansing the privies	£29,295
„ „ disposing of the sewage	21,931
Total	£51,226

or about 2*s.* 11*d.* per head of the population, or about 10*d.* in the pound on the rateable value of the borough.

The volume of sewage is at a rate of 34 gallons per head of the population, or about 6 persons contribute to every ton of sewage.

The capital, 132,174*l.*, will be paid off, when the rates will be relieved to the extent of about 1½*d.* in the pound on the present rateable value.

TREATMENT OF SEWAGE BY CHEMICALS.

Coventry.

Population (about)	40,000
Rateable value	£101,438
Houses	10,400
Waterclosets (about)	5,000
Privies	800
Quantity of refuse removed yearly (loads)	6,600
Cost of cleansing privies yearly and removing contents	£1,050
Amount received for refuse	110
Consequent loss on removal	£940

or at the rate of 2*s.* 10*d.* per load, or 5¾*d.* per head of population.

Expenses incurred to dispose of the Sewage.

Purchase of farm for irrigation at Whitley, not used for that purpose, but let at an annual rent of 718*l.*	£27,000
The yearly cost to the corporation of disposing of the sewage is	*Nil.*

The Yearly Cost to the General Sewage and Manure Company is as under:

Cost of works and plant	£12,000
Capital 12,000*l.* at 6 per cent. to repay principal and interest. Annual instalment	720
Working expenses of the process for treating the sewage 122½ hours weekly instead of 168 hours	2,850
	£3,570

The daily mean flow of the sewage is 2,000,000 gallons = 8,938 tons or 3,258,370 tons yearly. The annual cost to the General Sewage and Manure Company in disposing of the sewage is 3,570*l.*, and as there is not a sale for the manure produced from the process carried out by the company, the consequent loss is the above named amount equal to about one-fourth of a penny per ton of sewage, or at the rate of 1*s.* 9¼*d.* per head of the population.

The yearly loss on the cleansing of the privies - -	£940
The yearly loss in disposing of the sewage - -	3,570
	£4,510

or at a rate of about 2*s.* 3*d.* per head of the population or about 9½*d.* in the pound on the rateable value of the city.

The volume of sewage is at a rate of 50 gallons per head of the population, or about 5 persons contribute to every ton of sewage.

BOLTON-LE-MOORS.

Population (about) - - - - -	93,100
Rateable value - - - - - -	£311,563
Houses - - - - - -	18,249
Waterclosets - - - - - -	758
Privies and middens - - - - -	10,380
Privies, "pail system" - - - -	700
Weight of refuse removed yearly from privies on both systems (tons) - - - - -	51,290
Yearly cost of cleansing privies on both systems and removing contents - - - - -	£6,645
Amount received for refuse - - - -	4,494
Consequent loss on removal or at the rate of 10*d.* per ton, or 5½*d.* per head of population - - -	£2,151

CAPITAL EXPENSES incurred to DISPOSE of the SEWAGE.

Intercepting sewers - - - - -	10,286
Sewage defæcating works - - - -	16,578
	£26,864

The YEARLY COST of DISPOSING of the SEWAGE.

	£	*s.*	*d.*
Capital 26,864*l.* at 6 per cent. to repay principal and interest. Yearly instalment - -	1,609	18	4¾
Cost of treating the sewage by the M. C. process for only 57½ hours a week, instead of continuously for 168 hours in every week of seven days - - - - - -	1,006	17	0
	£2,616	15	4¾

The daily mean flow of the sewage is about 2,500,000 gallons = 11,161 tons or 4,073,765 tons yearly. The annual cost to the Town Council in disposing of the sewage is 2,616*l.* 15*s.* 4¾*d.* or at the rate of about one-eighth of a penny per ton, or 6¾*d.* per head of population, and this is the consequent loss as there is no sale for the "sludge," the residuum of the process. If the sewage was treated for the whole of the 24 hours, and for every day in the week by this process, the loss would be at the rate of about three-eighths of a penny per ton, or 1*s.* 8¼*d.* per head of the population, and this, too, for only about one-half of the sewage of the borough, for the other half flows direct into the river.

The yearly loss in cleansing the privies - -	£2,151
„ „ in disposing of the sewage - -	2,617
	£4,768

or at a rate of 1*s.* 0¼*d.* per head of the population or 3½*d.* in the pound on the rateable value of the borough.

The volume of sewage is at a rate of 27 gallons per head of the population, or eight persons contribute to every ton of sewage.

The capital, 26,864*l.* will be paid off in 30 years, and then the rates will be relieved to the extent of about 1¼*d.* in the pound on the present rateable value.

LEEDS.

Population (about)	285,000
Rateable value	£945,141
Houses (about)	57,000
Waterclosets (about)	8,000
Privies and middens	15,598
Quantity of refuse removed yearly from privies and middens — loads	80,000
Cost of cleansing privies and middens yearly, and removing contents	£27,000
Less amount received for the refuse	9,000
Consequent loss on removal	£18,000

or at the rate of 4*s.* 6*d.* per load; or about 1*s.* 2¾*d.* per head of the population; or 4½*d.* in the pound on the rateable value of the borough.

EXPENSES incurred to DISPOSE of the SEWAGE.

Experimental and permanent works for A. B. C. process	£57,000
Borwick's machines for drying sludge	4,000
	£61,000

The YEARLY COST of DISPOSING of the SEWAGE.

Capital, 61,000*l.* at 6 per cent. to repay principal and interest. Yearly instalment	£3,660
Yearly cost of treating the sewage by A. B. C. process	15,000
	£18,660

The daily mean flow of the sewage is about 12,000,000 gallons, = 53.571 tons, or 19,553,415 tons yearly. The annual cost to the town council in disposing of the sewage is 18,660*l.*, or at the rate of about one-fourth of a penny per ton, or 1*s.* 3½*d.* per head of the population, or about 4¾*d.* in the pound on the rateable value of the borough, and this is the consequent loss, there being no sale for the "sludge," the residuum of the process.

	s.	*d.*
Loss per head in cleansing privies	1	2¾
Loss per head in disposing of the sewage	1	3½
	2	6¼

The yearly loss on cleansing the privies	£18,000
The yearly loss in disposing of the sewage	18,660
	£36,660

or at the rate of 2*s.* 6¼*d.* per head of the population, or 9¼*d.* in the pound on the rateable value of the borough.

The volume of sewage is at a rate of 42 gallons per head of population, or about six persons contribute to every ton of sewage.

The capital, 61,000*l.*, will be paid off, and then the rates will be relieved to the extent of about 1*d.* in the pound on the present rateable value.

BRADFORD.

Population (about)	173,723
Rateable value	£745,671
Houses	34,000
Waterclosets	4,050
Privies	11,500
Ashpits	16,500
Weight of refuse removed yearly from privies on both systems, tons	56,200
The yearly cost of cleansing the privies and ashpits, and removing refuse which is the property of the contractor	£8,000
Railway waggons for carrying refuse, cost 4,800*l.* at 6 per cent., to repay principal and interest in 30 years	288
Consequent loss on removal	£8,288

or at the rate of 11½*d.* per head of the population, or about 2¾*d.* in the pound on the rateable value of the borough.

EXPENSES incurred to DISPOSE of the SEWAGE.

Outfall works, tanks, and so-called filters	£60,000

The YEARLY COST of DISPOSING of this SEWAGE.

Capital 60,000*l.* at 6 per cent. to repay principal and interest. Yearly instalment	£3,600
Yearly cost of defæcating the sewage	6,276
Total	£9,876

The mean daily flow of sewage is about 8,000,000 gallons, = 35,714 tons, or 13,035,610 tons yearly. The annual cost to the corporation in disposing of the sewage is 9,876*l.*, or at a rate of about one-sixth of a penny per ton, or 1*s.* 1⅝*d.* per head of the population, or about 3¼*d.* in the pound on the rateable value of the borough, and as there is no sale for about 7,000 tons of sludge yearly produced, the consequent loss to the borough is the above stated sum.

Yearly loss in cleansing privies	£8,288
Yearly loss in disposing of sewage	9,786
Total	£18,074

or at a rate of 2*s.* 1*d.* per head of the population, and about 6*d.* in the pound on the rateable value.

The volume of sewage is at a rate of 46 gallons per head of the population, or about five persons contribute to every ton of sewage.

The capital, 60,000*l.*, when paid off, will relieve the rates to the extent of about 3¼*d.* in the pound on the present rateable value.

HALIFAX.

Population (about)	68,000
Rateable value	£262,581
Houses	11,218
Waterclosets	2,600
Privies on old system	1,500
Privies on the "Goux" system	3,159
Yearly cost to the corporation of cleansing "Goux" privies	£1,896
Yearly cost to the corporation of cleansing common privies	1,100
	£2,996

The content is the property of the company and the contractor, and the consequent loss to the corporation is 2,996*l.*, or at the rate of about 10¾*d.* per head of the population.

EXPENSES incurred to DISPOSE of the SEWAGE.

Outfall works and tanks	£15,954
Cost of chancery suit	4,100
	£20,054

The YEARLY COST of DISPOSING of the SEWAGE by SUBSIDENCE only.

Capital 20,054*l.* at 6 per cent., to repay principal and interest.—Yearly instalment	£1,202
Cost of cleaning out tanks	213
	£1,415

The mean daily flow of the sewage is 2,500,000 gallons, = 11,160 tons, or 4,073,400 yearly. The annual cost to the town council in disposing of the sewage is 1,415*l.*; the sewage is not utilized, and they consequently lose the above amount.

Yearly loss of cleansing privies on both systems	£2,996
Yearly loss in disposing of the sewage by subsidence only	1,415
	£4,411

or at a rate of 1*s.* 3½*d.* per head of the population, or 4*d.* in the pound on the present rateable value of the borough.

The volume of sewage is at a rate of 37 gallons per head of the population, or about six persons contribute to every ton of sewage.

The capital, 20,054*l.*, will be paid off, and then the annual payment of 1,202*l.* will cease, when the rates will be relieved to the extent of about 1*d.* in the pound on the present rateable value.

TREATMENT OF EXCRETA BY THE PAIL SYSTEM.

ROCHDALE.

Population (about)	67,000
Rateable value	£222,000
Houses	14,388
Watercloset	350
Privies on old system	2,844
Privies on the "pail" system	5,462

EXPENSES incurred to CLEANSE PRIVIES constructed on "pail" system.

Cost of works and plant (about)	£10,000
Weight of excreta removed in 1875, from privies on "pail" system (tons)	4,224
Weight of house ash removed to be mixed with excreta (tons)	7,650
	11,874

The Yearly Cost of cleansing the Pail Privies.

Capital 10,000*l.* at 6 per cent. to repay principal and interest in 30 years. Yearly instalment - - -	£600
Or at the rate of 1*s.* per ton of excreta and ash.	
Cost of collection—11,874 tons of excreta and ash -	3,405
Or at a rate of 5*s.* 8¾*d.* per ton.	
Cost of manufacturing manure - - -	3,651
Or at a rate of 5*s.* 4½*d.* per ton.	
	7,656
Or together 12*s.* 1¼*d.* per ton.	
Less 2,002 tons manure sold at the estimated value of 1*l.* per ton - - - - - -	2,002
	£5,654

There is not a ready sale for the manure; consequently there is in stock at the works about 7,000 tons, and none of the excreta have since April 1875 been manufactured into manure.

The Yearly Cost of cleansing the Privies and Middens.

Weight of refuse removed (tons) - - -	13,736
Cost of cleansing - - - - -	£1,919
Or at a rate of 2*s.* 9½*d.* per ton.	
Amount received for 5,736 tons sold, the remainder 8,000 tons are thrown away on "tips" - -	549
Consequent loss - - - - - -	£1,370

Or at a rate of about 2*s.* per ton, or about 4¾*d.* per head of the population.

Expenses incurred to only intercept the sewage, and not defæcate it, and to discharge it into the river below the town mill-weir—

Cost of sewer - - - - - -	20,000*l.*
Capital 20,000*l.* at 6 per cent. to repay principal and interest. Yearly instalment - - - - -	1,200*l.*

The daily mean flow of the sewage is 1,250,000 gallons = 5,580 tons or 2,036,700 tons yearly. The annual loss to the Corporation in constructing the intercepting sewer is 1,200*l.* or at a rate of one-fourth of a penny per ton of sewage, or 4½*d.* per head of the population.

The yearly loss on cleansing the privies "pail" system is	£5,654
The yearly loss on cleansing the privies and middens -	1,370
The yearly loss in constructing the intercepting sewer -	1,200
	£8,220

Or at a rate of 2*s.* 5½*d.* per head of the population, or 8¾*d.* in the 1*l.* on the rateable value of the Borough.

The borrowed capital 10,000*l.* for the pail system, which involves an annual payment of 600*l.*, will cease at the end of the term for which this sum has been borrowed.

The volume of sewage is at a rate of 19 gallons per head of the population, or about 12 persons contribute to every ton of sewage.

COMPARISON OF THE LOSS OF DISPOSING OF TOWN SEWAGE IN PROPORTION TO THE ANNUAL RATEABLE VALUE OF THE TOWN.

BY IRRIGATION PLUS SCAVENGING.

Name of Town.	Annual Rateable Value.	Annual Cost in the Pound.
1. Banbury	£34,104	1*d.* in the pound.
2. Bedford	65,000	1*d.* „ „
3. Blackburn	235,127	1½*d.* „ „
4. Cheltenham	217,849	¾*d.* „ „
5. Chorley, Lancashire	54,407	7*d.* „ „
6. Doncaster	68,721	3½*d.* „ „
7. Harrogate	50,000	5¾*d.* „ „
8. Leamington	113,400	6½*d.* „ „
9. Merthyr Tydfil	135,000	7½*d.* „ „
10. Rugby	45,000	1½*d.* „ „
11. Tunbridge Wells	142,914	10*d.* „ „
12. Warwick	43,339	6½*d.* „ „
13. Wolverhampton	210,000	3½*d.* „ „
14. West Derby	163,000	5¼*d.* „ „
15. Wrexham	32,000	Nil.

BY CHEMICALS PLUS SCAVENGING.

16. Birmingham	£1,229,844	10*d.* in the pound.
17. Coventry, by a company	101,438	To the corporation, Nil for disposing of sewage; but at 5½*d.* in the pound for scavenging.
18. Bolton-le-Moors	311,563	3½*d.* in the pound.
19. Leeds	945,141	9¼*d.* „ „
20. Bradford	745,671	6*d.* „ „

BY THE PAIL SYSTEM AT ROCHDALE. The Crude Sewage flows into the River.

21. Halifax	262,581	4*d.* in the pound. The crude sewage flows into the river.
22. Rochdale	£222,000	8¾*d.* in the pound.

BY LAND FILTRATION AT KENDAL.

23. Kendal	£44,600	4*d.* in the pound.

This abstract is not in all respects a fair comparison of the relative costs the local rates will have to bear in some of the towns named, as in the case of Bolton, where not half of the sewage is dealt with, and even this is done in a manner which will not be sanctioned under a Rivers Pollution Prevention Act. At Rochdale the crude sewage of the town flows direct into the river, a state of things which certainly cannot be continued, and only a portion of the town is at present supplied with pails; and, as we have shown by working out the figures furnished in the local return, not quite one fourth of the excreta of the population said to be supplied with pails is accounted for.

Those towns which have purchased, or leased, land for sewage-farms, as Banbury, Bedford, Wrexham, Wolverhampton, Cheltenham, and Doncaster, show the best results, and levy the lowest rates, and we consider that longer experience will produce even much better results, and in time will show an available income. At Chorley, West-Derby, and Tunbridge-Wells there are good estates to set off against the money expended, the value of which estates will not diminish. At Leeds, Bradford, and Halifax there are only sewage-mud-tanks and so-called filters, with some unprofitable machinery which will not improve in value, and much larger costs must be incurred in these towns before all the sewage can be clarified in the best practicable manner. At Birmingham a large additional purchase of land upon which to purify the sewage is contemplated, and such expenditure will be the best yet made by the local authority. Birmingham is an instance of a town which would not move voluntarily; and then, being driven to extremities by legal restraints, worked unwillingly, bit-by-bit, and in sewering arrangements throwing the town back in its health returns, by compelling a retention of excreta upon the premises in the vain hope by such means to so lessen the polluting property of the sewage at the outlet as to avoid further litigation. Experience has, however, shown that stopping house drainage and discountenancing waterclosets has only slightly diminished the polluting property of the sewage, but not to any appreciable degree which can be accepted as a purification of the river water.

We have explained in this report that sewage, with or without the excreta from waterclosets is sewage, and that the entire excreta of a town population added to the waste-water is, by volume, only about as 1 to 100, consequently the capacity of sewers need not be enlarged; steam pumping power (if required) need not be increased, nor need the area of the land upon which to treat the sewage be added to; neither need there be one shilling more expended per annum on any process connected with the disposal of the sewage; but, on the contrary, the land irrigated will be made more profitable.

At Doncaster, Leamington, and Warwick the rates levied are for the purpose of paying the interest and instalments to redeem the large sums which have been expended upon steam-pumping establishments and cast-iron sewage-mains. At Tunbridge-Wells, West-Derby, and Merthyr-Tydfil, local conditions have necessitated large outlays of capital on the estates and the works for conducting the sewage to the sites, preparing the grounds, and constructing permanent sewage-carriers. These works have been very costly. Longer experience in working the farms will, we anticipate, by improving the income from the produce to be grown, very much lessen the present rates in aid.

It may be noted in the details of the several towns described, as at Blackburn, Harrogate, and at Tunbridge Wells, that very large sums have been paid in parliamentary and legal costs, and we have charged these items to the capital accounts in each case as against sewage irrigation, which of course increases the local rate, but it may fairly be said that such items are not necessarily parts of the expenses to be incurred in providing sewage-farms. Some towns suffer much more than others by reason of local opposition, and litigation before parliamentary committees, or, under the powers of the Lands Clauses Act, by arbitration. Land rented at 20*s.* or 30*s.* per acre, when required for a sewage-farm, is sometimes valued at several hundreds of pounds per acre, and in the case of Blackburn, portions of the land obtained for sewage irrigation purposes has cost about *one hundred and fifty years' purchase.* These difficulties and excessive charges very much retard local improvements and tend to throw the question of sewage irrigation back; it is, however, only a

repetition of opposition which every improvement in civilization has had to fight through.

The list of patents taken out to deal with town sewage (Appendix No. 6) shows how much interest the question has excited, and now excites, but large as this list is it furnishes only indirect evidence as to the vast sums of money expended and lost in working some of these patents. It would appear that to learn the lesson that money cannot be made out of sewage-sludge is very difficult, as over and over again it has been proven that there is no commercial value in it. The Leicester works proved this many years since, and every independent chemist of known repute has stated the fact when called upon to analyse sewage-mud. Neither is this mud capable of being fortified by an admixture of chemicals which shall give it a paying commercial value. The sludge is coarse, crude, sloppy, heavy, and very retentive of the water with which it is combined. In 100 tons of sewage-sludge, as it is removed from the tanks, there is not less than 90 tons of water, which in this form is worthless, and by itself the mud will not readily dry, but mixed with ashes, and other forms of towns refuse, it can be made portable and may then, in some cases, be sold to farmers at a low rate, say from 1*s.* to 2*s.* per ton. When the cost of carting is taken into account this will be its full agricultural value.

At Banbury the mixed sewage sludge, ashes, and street sweepings are given away, although the town is situate in an agricultural district.

At Leamington about 3,000 cube yards of solid refuse, costing 780*l.* to collect per annum, is also given away.

At Doncaster, Bedford, and Leamington, where the lands irrigated are light and free, the crude sewage is pumped direct to the land as it comes from the sewers, and being distributed from temporarily formed carriers, which at intervals are ploughed up. There is no nuisance, but the lands are benefited by the amount of warping they get. At Chorley the crude sewage is also placed on heavy land, which has however been drained.

At Cheltenham the sewage-farm is clay, and the area is small in proportion to the population, but dressings of sewage are sold to the adjoining farmers at a price per acre of 7*s.*, or as may be agreed upon; and in this direction we anticipate that many towns when they have established sewage-farms will find relief. In a dry season the contrast of the green fields of a sewage-farm with the parched, bare, and brown meadows adjoining is very striking. In the early spring the sewage farmer may have grass many weeks before there is any to cut upon ordinary meadows, and the weight of grass obtained is far in excess of any unirrigated crops.

We furnish plans of the sewage farms at Bedford, Doncaster, Tunbridge Wells, Wolverhampton, and West Derby. The details of sewage carriers, and modes of distribution can, however, only be learned to advantage by personal inspection.

Kendal is peculiarly situated, as the land upon which the sewage is clarified is light, open, and washed on its margins by the river, which conditions permit of land filtration over a small area, in comparatively large volumes, at a reasonable cost.

Analyses of Sewage-Sludge as treated and fortified with Chemicals.*

In order to ascertain the value of the fertilizing properties of sewage and excreta, and also of the manures manufactured therefrom, and of their commercial value to the farmer, we collected samples at Bolton, Bradford, Leeds, Coventry, Rochdale, and Halifax, and caused them to be analyzed by Dr. A. Voelcker, F.R.S., and the following is his report thereon:—

Report by Dr. Voelcker, F.R.S.—On the Fertilizing and Commercial Value of Sewage and Night-soil Manures.

The fertilizing and commercial value of sewage-sludge and of portable manures prepared from sewage, night-soil manures, and of common farmyard manure, chiefly depends upon the proportions of phosphate of lime, potash, and nitrogen which these fertilizers contain.

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* See also Appendices Nos. 1, 2, 3, 4.

These fertilizing constituents of manures can be bought at the present time in the form of concentrated artificial manures, such as guano, bone-dust, sulphate of ammonia, &c. at the following rates :

Phosphate of lime at - - -	1*d.* per lb.
Potash - - - - -	2*d.* „
Nitrogen calculated as ammonia at -	8*d.* „

I need hardly say that in such concentrated forms phosphate of lime, potash, and ammonia have a much greater value than they possess in the shape of manures, the bulk of which mainly consists of materials without value and occurring in abundance in almost every kind of soil.

I would, however, direct attention to the fact that according to my own experience, and that of others, sewage manures, night-soil manures, and ordinary farmyard manure contain but little ready formed ammonia, and that by far the largest proportion of the nitrogen in these manures occurs in them in the shape of nitrogenous organic matters, in which form nitrogen is less efficaceous ; and, in consequence less valuable than in the form of ready formed ammonia ; or, salts of ammonia.

In estimating the theoretical value of manures, the nitrogen is generally assumed to be present in sewage and similar bulky manures in the form of ammonia ; or, at all events, to have the same value as the nitrogen in the salts of ammonia. This, in my opinion, is a mistake, and the nitrogenous constituents of sewage manures are valued at too high a rate, if their nitrogen is calculated into ammonia, and 8*d.* allowed for each lb. of the calculated amount of ammonia. In order to avoid the charge of having put too low an estimate upon the fertilizing constituents of sewage-manures, I have allowed in the estimate 8*d.* per lb. for the calculated amount of ammonia, which the nitrogenous matters, in a ton of manure, are capable of gradually producing under the most favourable circumstances on their final decomposition.

The following tabular statement shows at a glance the theoretical or calculated money value of the different sewage manures which were submitted to me for analysis :—

THEORETICAL OR ESTIMATED MONEY VALUE OF ONE TON OF THE TREATED SEWAGE-SLUDGE.

	£	*s.*	*d.*
(1.) Bolton sludge, from the M. and C. sewage process* -	0	9	8½
(2.) The same dried, leaving 15 per cent. of moisture in the sludge - - - - - - -	1	1	1
(3.) Solids drained from sewage before the liming process at Bradford - - - - - -	0	11	0½
(4.) The same with 15 per cent. of moisture - -	0	19	3
(5.) Bradford Corporation Sewage Outfall Works sludge from drying pits, no artificial heat being used -	0	4	8
(6.) The same, with 15 per cent. of moisture - -	1	0	0½
(7.) Deposit from the sewage of Leeds treated by the A. B. C. process† - - - - - -	0	8	4½
(8.) The same with 15 per cent. of moisture - -	0	16	8½
(9.) Manure produced by the General Sewage Manure Company at Coventry - - - -	0	16	9½
(10.) Rochdale manure - - - - -	0	15	11½
(11.) Manure manufactured by the Goux Company at Halifax - - - - - -	0	17	7

According to the most reliable statements the separation of the suspended matters of sewage by precipitation and filtration, and the production of one ton of dried sewage deposits, apart from the costs of the precipitation agents which are used, entails an expense of about 30*s.* for each ton of portable dried sewage

* M. and C. are the initials of the patentees. The ingredients used are lime, carbon, house-ashes, soda, and per-chloride of iron.

† A. B. C. are the initials of the chief ingredients used in this process, as Alum, Blood, and Clay.

manure. It is evident, therefore, that the cost of manufacture considerably exceeds the theoretical or calculated money value of every one of the sewage deposit manures, the composition of which is given in the results of analysis in Appendices Nos. 1, 2, 3, pages 39, 43, 44, 48, 51, 54, and 59. The estimated money value of sewage and night-soil manures, as has been stated already, does not fairly represent their real commercial value. The bulk of all the samples submitted to me for analysis consists of matters which occur in abundance in almost all soils, and which at any rate have no commercial value, or rather, have a negative value, inasmuch as carriage has to be paid for them, and the application of bulky manures necessarily is more expensive than that of concentrated manures, such as guano or bone-dust. It is, therefore, manifestly practically wrong to estimate the money value of such bulky and poor manures by the same standard of prices at which the commercial value of guano, bone-dust, sulphate of ammonia, and similar concentrated artificial manures are estimated. A more rational and correct estimate of the true value of sewage and night-soil manures is obtained by comparing them with ordinary farmyard manure, and the price which is paid for the latter.

Good farmyard manure, I find, contains on an average in the ton 6½ lbs. of soluble phosphate of lime, 8½ lbs. of insoluble phosphate of lime, 13 lbs. of potash, and nitrogen equal to 17½ lbs. of ammonia.

By allowing for soluble phosphate of lime 2*d.* per lb., the same price for potash, 1*d.* per lb. for insoluble phosphate of lime, and 8*d.* per lb. for ammonia, the calculated money value of a ton of farmyard manure amounts to 15*s.* 7½*d.*, as will be seen from the following figures :—

	s.	*d.*
6½ lbs. of soluble phosphate of lime, worth, at 2*d.* per lb.	1	1
8½ lbs. insoluble „ „ 1*d.* „	0	8½
13 lbs. potash „ „ 2*d.* „	2	2
Nitrogen equal to 17½ lbs. of ammonia, calculating ammonia at 8*d.* per lb. - - - - -	11	8
Total calculated money value of a ton of farmyard manure - - - - - -	15	7½

It thus appears that if we estimate the money value of good farmyard manure, according to the same rules at which the principal fertilizing constituents in the dung can be bought in concentrated manures, one ton of farmyard manure would be worth, in round numbers, 15*s.* However, good dung can be bought in many places at 5*s.* per ton, or one-third its estimated money value; and practically the highest price which a farmer can afford to pay for good dung, if he has to cart it even a few miles, would not exceed 7*s.* 6*d.* per ton, one half its estimated money value. The difference between the estimated money value of farmyard manure (calculated at the market rate of the constituents, when sold as concentrated artificial manures), and the actual market price, may be fairly taken to represent the difference in practical value caused by the greater expense of the carriage and application of farmyard manure, and the less vigorous action of organic nitrogenous compounds as compared with ammonia salts.

In estimating the commercial value of sewage and night-soil manure, the calculated value of which does not exceed 1*l.* 1*s.* per ton, precisely the same circumstances have to be taken into account, which affect so largely the market value of ordinary farmyard manure. Accordingly the price which the farmer can afford to pay for the sewage and night-soil manures, analysed by me, or their real money value, will be only from one third to one half that of the calculated estimates given on the basis of their analyses.

The following table shows the market price or real money value of the various sewage and night-soil manures, samples of which were submitted to me for analysis :—

PRACTICAL OR MARKET VALUE OF ONE TON OF THE TREATED SLUDGE.

	s.	d.		s.	d.
(1.) Bolton sludge from the M. and C. sewage process	3	3	to	4	10
(2.) The same sludge 15 per cent. of moisture	7	0	„	10	6
(3.) Solids drained from sewage before the liming process, at Bradford	3	8	„	5	6
(4.) The same with 15 per cent. of moisture	6	5	„	9	6
(5.) Bradford Corporation Sewage Outfall Works. Sludge from drying pits without artificial heat	1	6	„	2	4
(6.) The same dried with 15 per cent. of moisture	6	8	„	10	0
(7.) Deposit from the sewage of Leeds treated by the A. B. C. process	2	9	„	4	2
(8.) The same sludge with 15 per cent. of moisture	5	6	„	8	4
(9.) Manure produced by the General Sewage Manure Company at Coventry	5	6	„	8	4
(10.) Rochdale manure	5	4	„	8	0
(11.) Manure manufactured by the Goux Company at Halifax	5	10	„	8	9

In my judgment this tabular statement fairly represents the money value of 11 different samples sent to me for analysis at the place where the manures were produced.

Some of the products are worth a good deal less than an equal weight of common dung, which fully explains the circumstance that most sewage manures find no ready sale, even at a low price, and that in many works such manures accumulate to an inconvenient extent.

Indeed comparatively few farmers are so situated that they can afford the expense of carting semi-dried sewage sludge containing from 60 to 70 per cent. of moisture from the works to their fields. The refusal to accept such sludge as a gift in not a few instances rather shows sound discrimination than ignorance on the part of the farmers.

(Signed) AUGUSTUS VOELCKER.

APPENDICES.

APPENDIX No. I.—SEWAGE FARMS.

Abstracts from these separate Reports of the different systems are given in our Report.

EDINBURGH.

The city of Edinburgh has a population of about 196,979, living in 10,559 houses, in which there are 41,615 separate dwellings on the "flat" system. The volume of sewage is about 5,900,000 gallons per day. Sewerage works have from time to time been carried out the old sewers being of rude construction in which sewage stagnates, hence its black and foul condition at the several outlets. Main-sewering is stated to have been commenced about the year 1778, and the system has been extended from time to time, especially in the New-town as it has increased, and works of a better class are still in progress. The oldest main-sewers are built of rough stone, with flat stone bottoms and stone covers, having a sectional area of 18 feet (6 feet by 3 feet); the cost of the older sewerage has been 69,000*l.* Since 1853 main-sewerage works have been greatly extended at a further cost of 80,000*l.* and in the valley of the water of Leith, a sewer has been constructed to intercept sewage and the refuse from paper and other mills, and pass the same by a cast-iron outlet-pipe (costing with the other works 85,000*l.*), into the Frith of Forth at "Black Rocks." These works serve for a population of about 100,000. The sewers of Edinburgh are not regularly flushed, and are not at present sufficiently ventilated; several springs were tapped during the execution of the main-sewerage works, the water being taken into the sewers, and it is estimated that the daily volume from this source is equal to about 40,000 gallons.

There are in Edinburgh at present many waterclosets, and in the older and more crowded parts of the city, 9 Macfarlane's latrines and 35 public privies; but the excreta and other refuse of the inhabitants in the Old-town are chiefly collected in pails or pans, placed in the living rooms; these receptacles are said to be taken down every morning into the streets, and their contents emptied into the corporation carts and

so removed. The waterclosets and latrines are connected with the sewers; the privies are emptied by men employed by the corporation. The annual gross cost of cleansing the city of this excremental matter and house refuse is 23,645*l.*, the corporation receiving 7,458*l.* for 36,637 tons, which is sold to farmers to be used as manure. The sewage is not treated by lime or by any other disinfectant, nor is it filtered, and by far the larger portions from the southern and western parts of the city flow into the Jordon, Broughton, and Lochrin burns, and from thence, unutilized, into the Frith of Forth.

The sewage of certain districts of the city has long been used in rough and rude irrigation, in some cases since 1760, the lands irrigated being known as the "Craigentinny meadows" which have an area of about 220 acres, "Lochend meadows" about 28 acres, "Lochrin-on-Dalry meadows" about 40 acres, and "Brigend and Cairntows meadows" about 35 acres, making a total of 323 acres. There are about 250 acres of the Craigentinny and Lochend meadows under sewage irrigation; of these 200 acres are permanent pasture grasses, and 50 acres Italian rye grass. About 2,500,000 gallons of crude sewage, every 24 hours, flows through the "Foul Burn" on to the meadows. The grass is sold by public roup at the beginning of April in each year in allotments of from half a statute acre to one acre in area, at prices varying from 20*l.* to 40*l.* per acre per annum; one allotment (acre) sold last year for 44*l.* 15*s.* The permanent grass is used for cow feeding and is bought by dairymen at Musselburgh, Portobello, Leith, and Edinburgh, who have to cut and remove it; this is done about four times in the season, and yields an aggregate crop of about 40 tons to the acre. The Italian rye grass is cut five times a year and produces occasionally 60 tons to the acre. The irrigation is carried on in the cheapest and rudest way by the owners of the land adjoining the streams into which the sewage flows; no cost having been incurred in providing permanent carriers of either wood, iron, stoneware, or brickwork. A considerable portion of the sewage is absorbed by the "sea sand" of which the irrigated meadows of Craigentinny farm is composed, and thus the soakage of sewage from this land into the "Frith of Forth" is only partially purified.

The area of the meadows under irrigation is not sufficient to utilize the whole of the sewage brought down by the "Foul Burn," consequently a greater extent of crop might be obtained if the sewage could be applied to other portions of the farm or to the adjoining lands.

The annual cost of applying the sewage and receipts for the produce are,—

Receipts.	£	Expenditure.	£
250 statue acres of grass at average of 30*l.* per acre	7,500	Wages of watermen three in summer and one in winter, and cost of cleaning out carriers - - -	180
		Estimated rent of land 250 acres at 2*l.* per annum * - - - -	500
		Balance - - -	6,820
	7,500		7,500

The effluent water was flowing into the "Frith of Forth" at the date of our visit in August 1875.

* This is a price far above its agricultural value without the sewage. See analysis by Dr. Voelcker.

If the 2,500,000 gallons of sewage were used in irrigation on these 250 acres of land, each acre would receive upwards of 16,000 tons in the year, and this, valued at 1*d.* per ton, would be worth 67*l.*

We have caused an analysis to be made by Dr. A. Voelcker, F.R.S., of the Craigentinny meadows soil, and the following is the result:

RESULTS by ANALYSIS of a SAMPLE of SOIL taken from the CRAIGENTINNY MEADOWS, EDINBURGH.

Dried at 212 F. the soil contained in 100 parts:—

*Organic matter	1·60
Oxide of iron and alumina	1·04
Phosphoric acid	0·06
Sulphuric acid	traces
Lime	0·08
Magnesia	0·25
Potash	0·08
Soda	0·13
Chloride of sodium	0·02
Silica (as white fine sand)	96·80
	100·06
*Containing nitrogen	0·039
Equal to ammonia	0·047

This soil, it will be seen, contains but very little lime, potash, and phosphoric acid, and thus is poor in all the more valuable mineral soil constituents.

It contains in round numbers only 1½ per cent. of organic matter in the perfectly dried soil, and in that state nearly 97 per cent. of fine white sand. The organic matter was present mainly in the shape of roots and vegetable fibres remaining in the land from the crops grown upon it. It is hardly necessary for me to state that the soil from the Craigentinny meadows, Edinburgh, analysed by me is one characterized by extreme natural sterility. The entire value is in the sewage, and the amount realised by the crop is about one halfpenny per ton, less the rent of the land and the cost of the labour.—See pages 78, 79, and 80 as to raw and effluent sewage.

BANBURY.

Population (about)	12,000
Rateable value	£34,104
Houses	3,485
Waterclosets	2,485
Cost of main sewers	£6,400
Cost of outlet works and laying out sewage farm	£5,500
Volume of sewage every 24 hours (gallons)	320,000
Cost of pumping sewage and working expenses of farm	£1,281
Amount received for produce	£1,451

Banbury.—This town of 12,000 inhabitants, living in 3,485 houses distributed over an area of 3,920 acres, and having a rateable value of 34,104*l.*, has finally adopted irrigation as a remedy for the pollution

caused to the River Cherwell by the unpurified sewage of the town flowing into it. The town was sewered in 1856, and 2,485 waterclosets were connected with the system; the main outfall being into the River Cherwell. In order to prevent the coarser suspended matters of the sewage from flowing direct into the river, subsidence-tanks were constructed, and through these tanks the sewage flowed before it reached the river, but this did not remove the soluble matters of the sewage, causing serious annoyance to Mr. John Spokes of Tyford, whose mill is on the Cherwell, about five miles below Banbury, he complained of the nuisance, and meeting with no redress, filed a bill in the Court of Chancery on the 20th June 1864, and on the hearing of the cause, the Vice-Chancellor, Sir W. Page Wood, issued an injunction to restrain the Banbury Local Board from causing or permitting the main sewers of the town and district to discharge the sewage into the Cherwell. The Local Board were advised "that the sewage should be treated by per-chloride of iron and caustic lime in the state of so-called 'milk,' and in the proportion of 20 grains of the former and 10 grains of the latter to every gallon of liquid sewage, and the treated sewage be allowed to flow slowly through the tanks to enable the mechanically suspended and chemically separated matters to be effectually deposited, and the supernatant liquid to pass off clear and nearly colourless; and they were advised that there would then be little likelihood of the sewage becoming again putrescent after its admission into the water of the flowing river." On receipt of this report the Local Board caused additional tanks to be built, so that the sewage after treatment might remain in nearly quiescent state for about four hours before it flowed into the river; and the above process recommended by Mr. T. Hawkesley and Dr. H. Letheby was carefully carried on for some time, but failed to purify the sewage, and the Court, on the application of the Plaintiff, issued an order of sequestration. The Local Board then, as better advised, took on lease, from 11th day of October 1866, for 28 years, a farm at Warkworth, of 138 acres, the soil being a stiff loam upon a clay subsoil and had it laid out to receive the sewage, but, owing to the configuration of the land, it had to be pumped to a height of 21 feet; and 320,000 gallons has been daily pumped on to the land ever since the farm was laid out, in winter as well as in summer. Subsequently, the Local Board received sanction to purchase the before-mentioned land and an additional area of 100 acres, making together 238 acres, costing the sum of 23,400*l*. There is storeage in the tanks at the pumping station for eight hours flow of sewage; these tanks are cleaned out every six weeks, and the refuse mixed with the dry house ashes and street sweepings, was formerly sold at 6*d*. per ton, but, in consequence of an accumulation of nearly 2,000 tons, and there being no sale for it, the refuse with the street sweepings are now allowed to be taken away from the depôt free of charge.

The privies are cleansed at the cost of the occupiers of the houses to which they belong.

The rainfall on the roofs and the surface of the streets flows into the sewage-drains, and thence to the outfall, and has to be pumped to the farm, except in heavy rainfall, and then the storm water flows by the storm-outlet into the Cherwell. The sewers are ventilated at present, partially and imperfectly, by down spouts from the roofs of houses, and also by a few grids on the surface of the street. The cost

of the main sewers was 6,400*l.*; of the tanks and buildings 1,500*l.*; and of pumping-station, rising-main and laying out farm 4,000*l.*

The accounts of the receipt and expenditure for the year 1875 are as follows:—

BANBURY LOCAL BOARD OF HEALTH SEWAGE FARM SALES, &c., 1875.

Name of Field and Date of Sale.	Description of Crop.	Quantity sold.	Product of Sales.	Amount per Acre.
		Acres Chains	£ s. d.	£ s. d.
Great between Brooks.				
April 30 1st cutting -	Rye grass	6 3	28 19 0	4 11 11
June 11 2nd „	„ „	5 9½	41 13 0	7 0 0
July 30 3rd „	„ „	5 9	42 16 0	7 5 1
September 17 4th „	„ „	5 7	11 18 0	2 1 9
			125 6 0	20 18 9
May 14 1st cutting -	„ „	8 2	41 18 0	5 2 2
June 25 2nd „	„ „	8 2	55 13 0	6 15 9
August 13 3rd „	„ „	7 3¾	39 18 0	5 8 2
October 8 4th „	„ „	5 9½	6 0 0	1 0 2
			143 9 0	18 6 3
West between Brooks.				
May 28 1st cutting -	„ „	6 8½	40 18 0	5 19 5
July 16 2nd	„ „	7 3½	37 9 0	5 1 10
September 3 3rd „	„ „	5 9¼	18 0 0	3 0 10
			96 7 0	14 2 1
October 22 - -	Mangold wurtzel	2 0	17 15 0	8 17 6
East between Brooks.				
October 22 - -	Mangold wurtzel	11 1¼	162 6 0	14 11 8
Horse Stub.				
August 13 - - -	Wheat	8 5	102 0 0	12 0 0
„ 13 - - -	Oats	8 7½	122 10 0	14 0 0
			224 10 0	26 0 0
Great Bolland.				
May 28 1st cutting -	Mowing grass	24 5	132 2 6	5 7 10
August 13 2nd „ -	„ „	24 5	58 0 0	2 7 4
September 17 „ „ -	Aftermath	24 5	12 5 0	0 10 0
			202 7 6	8 5 2
Little Bolland.				
May 28 1st cutting -	Mowing grass	13 0	79 12 6	6 2 6
August 13 2nd „ -	„ „	13 0	40 12 6	3 2 6
September 17 „ „ -	Aftermath	13 0	14 19 0	1 3 0
			135 4 0	10 8 0

Name of Field and Date of Sale.	Description of Crop.	Quantity sold.	Product of Sales.	Amount per Acre.
		Acres Chains	£ s. d.	£ s. d.
Upper Plain.				
May 28 1st cutting -	Mowing grass	14 0	75 5 0	5 7 6
August 13 2nd „ -	„ „	14 0	28 0 0	2 0 0
September 17 „ „ -	Aftermath	14 0	11 14 0	0 16 0
			114 19 0	8 3 6
Middle Plain.				
May 28 1st cutting	Mowing grass	13 5	62 8 9	4 12 6
August 13 2nd „ -	„ „	13 5	27 0 0	2 0 0
October - - -	Aftermath	13 5	6 10 0	0 9 7
			95 18 9	7 2 1
Lower Plain.				
May 28 1st cutting -	Mowing grass	12 5	57 16 3	4 12 6
September 3 2nd „ -	„ „	12 5	22 10 0	1 16 0
„ 17 - -	Aftermath	12 5	5 12 6	0 9 0
			85 18 9	6 17 6
Right of shooting for the season -		- - -	4 0 0	
Keep of four horses - - -		- - -	43 8 0	
		Total £	1450 19 0	

The whole of the crops are sold standing, the Board being at no expense of cutting or carting.

SUMMARY.

Receipts.	Area. A. C.	Product of sales. £ s. d.	Average per acre. £ s. d.	Expenditure.	£ s. d.
Permanent pasture -	77 5	633 18 0	8 3 7	Rent (less Property tax) - - - -	622 0 0
Rye grass (including horse keep).	24 4½	408 10 0	16 14 2	Rates and taxes - - - -	39 12 8
Wheat - -	8 5	102 0 0	12 0 0	Superintendence and manual labour (including engine driver).	247 14 5
Oats - - -	8 7½	122 10 0	14 0 0	Oil seed, &c. - - - - -	76 7 5
Mangold wurtzel -	13 1½	180 1 0	13 14 4	Coal - - - - - -	147 4 5
Right of shooting -	—	4 0 0	—	Own horse labour (about) - - -	30 0 0
				Manager's salary - - -	45 0 0
	132 3½	1450 19 0	—	Commission, &c. - - - -	72 11 6
	A. R. P.				
Total area of farm (including roads).	138 0 38	1450 19 0	10 9 11		£1,280 9 5

Mr. Thomas Garrett, the town surveyor and manager of the farm, has been successful in carrying off several silver cups and money prizes for the roots grown by sewage of the farm.

NOTE.—See pages 87 and 88.

BEDFORD.

Population (about)	18,000
Rateable value	£65,000
Houses	3,500
Waterclosets	3,000
Cost of main sewers	£19,000
Cost of outlet works, pumping station, and laying out sewage farm	£9,200
Volume of sewage every 24 hours (gallons)	700,000
Rent, labour, and expense of working farm	£3,280
Amount received for produce	£3,461

Bedford. This is an instance of a town which, without being forced by the expensive machinery of the Court of Chancery to get rid of the nuisance caused to the river by sewage pollution, has endeavoured to utilize its sewage by applying it to profitable use in irrigation. The Local Board District of Bedford has an area of 2,200 acres, and a rateable value of 65,000*l.*, with a population of about 18,000 living in 3,500 houses, to which are attached at least 3,000 waterclosets, and as there are no privies, this may truly be termed a watercloset town. A thorough system of sewerage has been carried out, commenced in 1864 and finished in 1868 at a cost of 19,000*l.* The old sewers are used as surface and storm-water conduits, and these have three outlets into the river Ouse. The whole of the sewage proper is intercepted from the river by the new sewers, and gravitates to a point at Newnham, about a mile from the town, where it flows into a sewage-well, and is thence pumped on to 155 acres of land, a small portion of which is the property of the corporation. The larger part is leased from the Duke of Bedford, the Rev. J. W. C. Campion, and Captain Polhill Turner. The soil of the farm is a rich loam with a gravelly sub-soil, well adapted for the purpose to which it is devoted, and the surface has been especially laid out for irrigation. The permanent carriers are stone-ware pipes, with side-junctions at proper intervals for regulating the flow of sewage on to the plots of land required to be irrigated. The volume of sewage which has to be pumped, is estimated at 700,000 gallons every 24 hours, but of this 300,000 gallons is sub-soil water. The main outfall sewer is 5 feet 3 inches by 3 feet 9 inches in sectional area, three quarters of a mile long; is laid at a gradient of 1 in 3,520, and serves as a storage-tank. The sewage-well, at the pumping-station, is of small capacity, and to prevent choking the pumps by the coarser particles of sewage, the suction-pipe is protected by iron screens.

The outfall-sewer is cleaned out occasionally, and the deposit which is little more than detritus is carted away.

The cost of preparing the land, constructing carriers, erecting pumping station, and fitting it with machinery was 7,200*l.*

By the courtesy of the town clerk we are enabled to give a copy of the General Account and Balance Sheet for the year ended 31st December 1874, and also proceeds from sales of crops for the year ended 31st December 1875.

The Urban Sanitary Authority for the Borough of Bedford.—Irrigation Farm.—General Account and Balance Sheet at Stock-taking 31st December 1874.

Dr.	£	s.	d.	£	s.	d.
Stock, December 1873	431	0	0			
Working plant, Dec. 1873	222	4	0			
				653	4	0
Labour, manager, and engineer				667	17	2
Tradesmen's bills, &c.				780	10	9
Rent				917	4	0
Rates and taxes				113	14	7
Permanent works				24	2	8
Oats				16	5	0
Hay	48	2	6			
Beans	59	10	0			
				107	12	6
Balance for 1874				189	15	4
				£3,461	6	0

Cr.	£	s.	d.
Sale of Crops	2515	13	10
Stock in hand and purchased, 1874	544	8	0
Working Plant and Live and Dead Stock.	269	9	0
Sewage Works	24	2	8
Hay	48	2	6
Beans	59	10	0
	107	12	6
	£3,461	6	0

Corn &c., for live stock.—

	£	s.	d.
Corn purchased, (see expenditure)	40	8	9
Hay from farm	48	2	6
Oats	16	5	0
Beans	59	10	0
	£164	6	3

	£	s.	d.
Labour	402	9	7
Manager	112	11	1
Engineer	62	16	6
	£667	17	2
Tradesmen's bills paid	79	11	7
Tradesmen's bills owing	30	10	2
Coals	260	2	7
Coals owing	32	8	0
Horse corn, &c.	40	8	9
Manure purchased	10	0	0
Horse and bullocks purchased	133	10	0
Seeds	102	8	4
Hire of Horses for ploughing	30	3	0
Mr. Stafford's commission and expenses.	114	12	6
	833	14	11
Deduct bills owing 1873	53	4	2
	£780	10	9
Rents—			
The Rev. Campion	126	14	11
Captain Polhill Turner	421	11	3
Duke of Bedford	244	8	2
Corporation of Bedford	123	9	8
L. & N. W. Ry.—Sewer under railway.	1	0	0
	£917	4	0
Poor Rates	92	0	3
Income Tax	18	3	2
Land Tax	3	1	2
Insurance	0	10	0
	£113	14	7
Permanent works	24	2	8

	£	s.	d.
By Sale of Crops, Mr. Stafford	1,933	1	1
Manager	582	12	1
	£2,515	13	10
Stock in hand and purchased, 1874—			
30 tons of hay, 5l.	150	0	0
26 loads of beans, 28/-	38	8	0
2 acres of mangolds, 20l.	40	0	0
6 tons of potatoes, 4l.	24	0	0
16 acres of growing wheat, 50/-	40	0	0
Bean, barley, and oat straw	15	0	0
Rye grass hay	10	0	0
Picking cabbages	12	0	3
Carrots	25	0	0
12½ oats, 26/- per qr.	16	5	0
6 acres of growing cabbage, 5l.	30	0	0
9½ acres of growing rye grass, 50/	23	15	0
8 bullocks, 15l.	120	0	0
	£544	8	0
Working plant and live and dead stock.			
4 horses	175	0	0
3 carts, 8l.	24	0	0
1 horse roll	7	10	0
1 double plough	3	0	0
1 single ditto	1	10	0
1 horse hoe	4	0	0
1 scuffler	4	0	0
2 sets of harrows	2	0	0
1 pulper	2	10	0
1 chaff cutter	4	0	0
1 bean mill	2	10	0
6 wheelbarrows	1	4	0
4 sets of Harness	6	0	0
1 cultivator	2	15	0
3 cow cribs	3	0	0
Office furniture	2	10	0
Coals in stock	24	0	0
	£269	9	0

J. E. Cutcliffe,
W. Roff,
Harry Thody,
Thomas Hall Barkham,
Jas. Thos. Hobson,
} Farming Committee.

BOROUGH OF BEDFORD. URBAN SANITARY AUTHORITY IRRIGATION FARM.

Account of Proceeds from Sales of Crops, year ending 31st December 1875.

—	Area under cultivation.			Amount.		
	A.	R.	P.	£	s.	d.
Italian rye grass	22	0	0	399	0	6
Potatoes	25	1	0	140	16	6
Mangolds	40	2	20	599	6	6
Onions	10	0	20	287	0	0
Carrots	7	3	0	116	1	0
Cucumbers	1	0	0	16	1	0
Vegetable marrows	0	0	10	1	6	3
Asparagus	0	0	20	2	11	0
Rhubarb	0	0	20	5	0	0
Cabbage	6	1	10	87	12	0
Pickling cabbage	1	1	0	34	18	8
Cauliflowers	6	0	0	60	0	0
Oats	14	0	0	135	0	0
Wheat	16	1	10	228	13	9
Permanent pasture	30	0	0	181	10	6
	180	3	30	£2,294	17	8

NOTE.—See pages 91, 92, 93, as to raw and effluent sewage.

BLACKBURN.

Population (about)	90,000
Rateable value	£235,127
Houses	16,700
Waterclosets	730
Volume of sewage every 24 hours (gallons)	1,500,000
Privies and middens	10,574
Privies, "pail" system	2,690
Ashpits	5,287
Yearly cost of cleansing privies on both systems	£5,641
Amount received for refuse	£1,806

The rateable value of *Blackburn* is 235,127*l.*, and a population of about 90,000 is here grouped together in 16,700 houses on an area of 3,620 acres. There are at present only 730 waterclosets in the borough, and the fæcal waste of the inhabitants is therefore principally disposed of by 10,574 of the "old Lancashire middens," and by 2,690 privies of more modern construction on the "pail" system; there are also 5,287 ashpits for collecting this form of house waste.

The borough has been sewered; the works were commenced in 1850, and finished in 1873, at a cost, including subsidence-tanks, of 78,245*l.*

The old drains have been utilized to convey the rainfall off roads and streets by 10 outlets into the river; whereas, the new drains are used for the sewage proper, and as all the old middens are drained into the new sewers, the composition of the sewage of Blackburn is very similar to that discharged from an entirely water-closeted town, the proportion of putrescible organic matter in solution in the sewage being slightly less, whilst the organic matter in suspension is somewhat greater.

The Rivers Pollution Commissioners caused numerous samples of the sewage of both midden towns and watercloset towns to be analysed in their laboratory, and from the results of these analyses, they were enabled to say:—"The retention of the solid excrements in 'middens' is not therefore attended with any considerable diminution in the strength of the sewage, although the volume even in manufacturing towns is somewhat reduced. It seems hopeless, therefore, to anticipate any substantial reduction of sewage pollution by dealing with solid excrementitious matters only."

In 1865 the main outfall sewer discharged direct into the "Blakewater," and caused serious pollution, not only to that river, but also to the Darwen into which the Blakewater emptied; the nuisance was complained of by the riparian owners, and a Bill was filed in the Court of Chancery by Sir William Fielden, Bart. (of Feniscowles), praying that the corporation might be restrained from polluting the river Darwen with the sewage of Blackburn, and an injunction was granted.

The defendants applied for time to enable them to cause remedial works to be constructed, and the Court gave the time asked for. The corporation then directed subsidence tanks to be built near the river Blakewater on the eastern boundary of the town, and caused the sewage to flow through these tanks and to be treated by the "lime-process" (*i.e.*, adding a certain proportion of "milk of lime" to facilitate deposition) before the sewage entered the river; but this did not sufficiently mitigate the nuisance, and although the supernatant liquid flowed off comparatively clear, the method failed to purify the sewage so as to render it admissible into the river, for at a short distance from the outlet of the sewage-tanks the river was still in a most offensive condition of putrefaction. The plaintiff then brought an action in the Court of Queen's Bench and laid the damages at 20,000*l.*; the case came on for trial and was referred to Mr. Manisty, Q.C., who found for the plaintiff, but only awarded to him 1,250*l.* damages, and costs; the cost of the suit in Chancery and the damages and costs in the action at law amounted however to about 12,000*l.*

The corporation then, as advised, determined to adopt sewage irrigation, and for this purpose promoted a Bill of Parliament in the session of 1870; there was great opposition to this Bill, but it was passed and it empowered the corporation to acquire 1,090 acres of land, in the townships of Pleasington, Houghton, and Samlesbury. The cost of obtaining the Act was 6,500*l.* In 1872 the corporation took on a lease, for 20 years, at the yearly rent of 484*l.* 179 acres of land in the townships of Pleasington and Houghton, and directed the outfall sewer to be extended to Higher Park, Pleasington, and 90 acres of the 179 acres, upon which the sewage would gravitate, to be drained and especially laid out to receive it. The works have been carried out a cost of 11,600*l.*, and about 1,500,000 gallons of sewage every 24 hours have flowed on to the farm, and have been used in irrigation ever since the works were completed. The 90 acres have been cropped this year (1875) 74 acres with Italian rye grass, and 10 acres with mangolds and turnips, whilst the remaining six acres of the land were in fallow and roads. In order to dispose of the produce without loss, the corporation purchased stock. The total expenditure for the year ended 31st December 1875, including working expenses, purchase of stock, and also a sum of 480*l.*, the cost of permanent improvements, was 6,523*l.* 2*s.* 9*d.*, and the receipts for the same period, including sale of fat stock, were 5,781*l.* 6*s.*, 10*d.* It is believed that this year (1876) the receipts will more than cover the expenses.

In order to extend their irrigation the corporation, in 1875, concluded

the purchase of 475 acres of land at Samlesbury, at a cost of 69,500*l.*, including expenses of arbitration, easements, &c., being at a rate of about 100 years purchase of the present rents, and they have directed their engineer to extend the sewage conduit on to this newly acquired land at an estimated cost of 7,650*l.*, to which the cost of draining and preparing the land must be added. The farm at Pleasington and Houghton has a light loamy soil upon a gravelly subsoil; it has been under drained to a depth of 4 feet, the drains being 18 feet apart. It is intended to drain the land at Samlesbury, which is partly loam and partly stiff clay.

In addition to the cost of disposing of the sewage in irrigation, there is the cost of cleansing the "middens" and the privies on the "pail" system; this amounts to 5,641*l.* 2*s.* 8*d.* yearly, and the annual receipts for the refuse from both kinds of privies is only 1,805*l.* 12*s.* 5*d.*

CHELTENHAM.

Population (about) - - - - - -	45,000
Rateable value - - - - - -	£217,849
Houses - - - - - - -	8,725
Waterclosets - - - - - -	8,500
Cost of outfall works, purchase and laying out of farm -	£18,000
Volume of sewage every 24 hours - - (gallons)	1,250,000

Privies are cleansed at the expense of the occupiers of the houses to which they belong.

Cheltenham.—The sewage of this township, which has an area of about 2,000 acres and a resident population, including portions of Charlton-Kings, Leckampton, and Prestbury, of about 45,000, living in 8,725 houses, and a rateable value of 217,849*l.*, is disposed of in irrigation. The natural drainage of the district is into three streams flowing from east to west, *i.e.*, Wyman's Brook on the north, the Chelt in the centre, and the Hatherley Brook to the south; all the sewage, however, runs towards the Chelt and the Hatherley Brook, near which streams the subsidence-tanks have been constructed, from which it flows, by gravitation through earthenware pipes to the farm. The local authority have in contemplation to conduct by pipes in a northerly direction a portion of the sewage from the tank near the Chelt on to land in the parish of Elmstone-Hardwicke, abutting on Wyman's Brook, and if the proposal be carried out, a great object will be obtained in bringing under sewage irrigation an extended area of land admirably adapted for the purpose; and as the owner and tenant of the land are willing to join in an agreement for 14 years, a degree of permanence will be assured; the tenant will take the responsibility of dealing with the sewage on his own land so as not to occasion nuisance or injury to others; he will also pay a fair rent for it. The watercloset system is generally adopted, there being about 8,500 in the town. The average volume of sewage every 24 hours is 1,250,000 gallons, and as stated above, this flows from the main outfall-sewer into subsidence-tanks, which are constructed with transverse divisions to intercept matters in suspension, and by an arrangement the sewage as it flows through the tanks works a turbine and chain pump; by this means the "sludge" is pumped up, and mixed with the house refuse and ashes, (about

3,234 cubic yards). There is no permanent accumulation of this refuse. The cost of cleansing the tanks and the receipts for the last three years are—

Year.	Cost of cleansing tanks and incidental works thereto.	Receipts for sale of sludge, mixed with ashes, from domestic fires.
	£ s. d.	£ s. d.
1873	237 9 8	293 7 4
1874	278 0 2	271 16 0
1875	296 6 1	347 5 0

Before irrigation was adopted, proceedings were threatened against the Improvement Commissioners, but no action arose, and in 1870 they purchased a farm of 131 acres (6 acres arable and 125 acres in permanent pasture) at Boddington on the western side of the town, and distant therefrom about two miles; the soil is a stiff clay, and the land has a gentle slope from east to west. The sewage is delivered by the earthenware conduit from the tanks on to the high part of the farm, it is occasionally applied to 200 acres of land adjacent to the conduit, for which the tenants pay to the Improvement Commissioners 7*s.* per acre for each dressing of sewage, amounting last year to the sum of 156*l.* The whole of the land at the farm, with a trifling exception, can be irrigated from the summit; there are various branch-pipes for the delivery of the sewage to different parts, and these branches are to a great extent laid in cuttings of a moderate depth, open-carriers having been found objectionable as the cattle trod them out of form, the land being grazed during the greater part of the year. The undulating form of the land, and the arrangement of the branch conduits at different levels afford facilities for passing the sewage again over the lower portion of the farm when it has been over the higher portion of it, and thus is insured more perfect purification of the water before it flows into the Chelt and Hatherley Brook. The sewage-farm has been let at a yearly rent varying from 815*l.* to 861*l.*, and is now let at a rent of 800*l.* per annum, subject to the Improvement Commissioners undertaking the duty of applying the sewage, at a cost in labour of 150*l.* a year, to which must be added the amount of rates and taxes which they also pay of about 50*l.* a year. There are only three residences, two homesteads, and about 20 scattered cottages near the farm. Previous to the adoption of irrigation, a process of treating the sewage by lime, per-chloride of iron and Bird's powder was tried, but the result was unsatisfactory. No complaint has ever been substantiated since the adoption of irrigation, and there is not now, even in hot summer weather, any nuisance caused by the effluent from the sewage farm. The cost of the sewerage works has been to the present time 53,400*l.*, including purchase and laying out of farm and building tanks.

CHORLEY.

Population (about)	20,000
Rateable value	£54,407
Houses	4,000
Waterclosets	200
Cost of outlet works, purchase, and laying out farms at Common Bank and Plymouth Bridge	£16,550
Volume of sewage every 24 hours (gallons)	500,000
Privies and middens	1,600
Privies, "pail" system	700
Cost of cleansing privies on both systems	£709
Amount received for refuse	£186

Chorley (*Lancashire*).—Area of the district 3,613 acres, population about 20,000; annual rateable value, 54,407*l*. There are about 4,000 houses, 200 waterclosets, and 1,600 privies, but these latter are being gradually abolished and the "pail" system introduced, and about 700 privies are now reconstructed on this system. The district, with the exception of a small area at Cowling and Botany, was sewered in 1855, at a cost of 17,000*l*., and the sewage then gravitated to one outfall in the river Chor. Complaints were repeatedly made to the Improvement Commissioners by the Reverend J. Sparkling, Mr. Henry Alison, Mr. R. Townley Parker, Mr. E. E. Silvester, and Mr. Randolphus de Trafford, riparian owners, of the nuisance caused by the sewage of the town being discharged into the river Chor and thence carried down into the river Yarrow, which polluted and rendered offensive the water of the Yarrow from the confluence of the Chor to below the village of Croston, and in July 1867 Mr. Edward Silvester and Mr. Henry Alison filed a bill of complaint in Chancery and prayed, "That the "defendants be restrained by injunction from causing or allowing the "sewage to be discharged, or to flow into the river Yarrow so as to be "a nuisance and pollute the said river." The defendants (the Chorley Commissioners) by their counsel admitted that the discharge of sewage into the Yarrow, by means of the Chor, had polluted the river, and that the works constructed by them had become a nuisance. A perpetual injunction was issued to restrain the defendants from continuing the same, such injunction not to take effect until the expiration of 12 months from the date of the decree, 23rd November 1867, or until the expiration of such further period as the Court should from time to time direct. With the intention of diverting the sewage from the Chor and Yarrow and utilizing it in irrigation the Improvement Commissioners, on the 21st October 1867, took on lease for 21 years, at a yearly rent of 130*l*., a farm of 87 acres, at "Common Bank," about a mile to the West of Chorley, and subsequently, in 1870, purchased it for 6,450*l*., and caused it to be laid out to receive sewage. The outfall-sewer was extended and continued on to the farm by cast-iron pipes; permanent carriers to distribute the sewage were also constructed of brickwork, stoneware-pipes and wood; and suitable farm buildings, were also erected; these works cost 4,800*l*. As soon as the works were completed, the sewage, which is estimated to be about 500,000 gallons every 24 hours, 200,000 of this being subsoil water, flowed continuously over the farm. The land, which is for the most part poor vegetable soil, with a stiff clay subsoil, has been underdrained to

a depth of 3 feet 6 inches, the drains being 16 feet apart. The local authority obtained power in 1871 to acquire additional land for the purpose of sewage utilization, and in 1875 purchased and laid out an area of 46 acres, part of "Kingsley's farm," at Plymouth Bridge, at a cost of 5,300*l.*; this land has a clay subsoil, and is arranged for the purpose of receiving the sewage of the Chorley Moor district. The Improvement Commissioners have since let this land with the sewage, at an annual rent of 90*l.*, the tenant undertaking to distribute and cleanse the sewage, so as not to cause a nuisance.

The sewers are ventilated by 120 open grids, in the surface of the streets near the manholes, by rain-water pipes from the eaves of buildings, by pipes carried up at the gable ends of buildings, and by connexion with the chimney-shaft of the Water Street mill. No complaint has been made of the state of the purified effluent water flowing from the sewage farm into the Yarrow.

The working of the "pail" system is an annual loss, costing more than cleansing privies and middens, but it is believed that the removal, once a week, of the excreta under the "pail" system, will improve the health of the inhabitants. The expense of cleansing the privies, and "pails" for the year ended 31st May 1875, was 708*l.* 15*s.* 4*d.*, and the receipts for the refuse were 186*l.* 3*s.*

The sewage farm was cropped in 1875, with oats 20 acres, Italian rye grass 20 acres, wheat 3 acres, Swedes 7 acres, while of permanent pasture and meadow there were 39 acres, and osiers 1 acre. The meadow land produced two tons of hay per acre, which sold at 7*l.* per ton; the Italian rye grass, in four cuttings, 10 tons per acre, and realized 16*s.* 8*d.* per ton; the oats yielded 50 bushels and 2 tons of straw per acre sold for 3*s.* 6*d.* per bushel and 70*s.* per ton; the swedes 15 tons per acre, and sold for 1*l.* per ton, and the 1 acre of osier realized 11*l.* There is a dairy of 11 cows kept on the farm; there are also 2 bullocks 24 young stock, and 5 pigs feeding. The farm is worked by 3 horses.

DONCASTER.

Population about 20,000.

Waterclosets are not generally used.

The town is sewered, and the houses are drained.

The volume of sewage flowing to the sewage pumps is about 600,000 gallons per day; or about 219,000,000 gallons per annum.

Flood-water from the surface of the town overflows to the rivers.

The 600,000 gallons of sewage is pumped daily on to the land of the Sewage Farm.

The works to store and pump the sewage have cost 20,000*l.*

The lift is 52 feet.

The Sewage Farm is 264 statute acres of light sandy land.

The rent was 25*s.* per statute acre.

The corporation pump the sewage, and obtain a rental of 800*l.* per annum, or about 3*l.* per acre.

The land has been three years under sewage cultivation; but only about 115 acres have received dressings of sewage in this time.

The entire pumping of one day, 600,000 gallons, has been disposed of over one acre.

The usual course is to distribute this volume of sewage over 5 acres.

Italian rye grass has received per acre in one year at a rate of 13,000 tons, or a vertical depth of sewage of 130 inches. The land during the season would readily have disposed of double this volume of sewage, 260 inches,—if it had been desirable so to dispose of it. The 130 inches were actually required by the grass.

Doncaster.—This borough has an area of 1,690 acres, a population of about 20,000, and a rateable value of 68,721*l.* 10*s.* There are in the borough 4,300 inhabited houses; the existing water supply is defective, consequently waterclosets are not generally used. The town has been sewered, but not more than one half of the excreta of the inhabitants flows to the pumping-station at the outfall-works. The main-sewers are of brickwork, and the branch mains of sanitary pipes. The sewers are ventilated by means of open grids in the covers of manholes at the street surface; and, in some instances, by pipes carried up the gable ends of the houses above the roofs. The sewerage works were completed in 1870, under the advice and superintendence of Mr. B. S. Brundell, C.E., and the sewage then flowed by an existing outlet into the river Don navigation. The proprietors of that navigation, in the autumn of 1870, filed a Bill of Complaint in Chancery, and obtained an injunction. The corporation, as advised, not having a defence, consented thereto, asked for time to be given in which to carry out remedial works, and the Court granted two years. The corporation then directed Mr. Brundell to examine and report on the best means of disposing of the sewage. This he did, and reported in favour of irrigation, advising that the sewage should be intercepted from the river and pumped on to land, the property of the Corporation at Long Sandall. Subsequently, the works, as designed, were carried out, at a cost, of 20,000*l.* The whole of the sewage of Doncaster, with the exception of that part of the town known as Bennetthorpe, consisting of about 80 houses, gravitates to a point on the north side of the town, and flows into a sewage-well, first passing through iron screens fixed across the well to prevent choking of the pumps by cotton-waste, rags, and shavings thrown into the sewers. A volume of crude-sewage, varying from 500,000 to 800,000, or an average of 600,000 gallons, is pumped daily from 6 a.m. to 11 a.m., and from 1 p.m. to 5.30 p.m. The outfall-sewer is of sufficient capacity (6 feet in diameter) to hold the dry-weather sewage flowing during the night; but in wet weather the sewage can be pumped, at night, into a tank on the farm, capable of holding 1,000,000 gallons. There is also a storm-outlet, by which the sewage, when extremely diluted by heavy rain-fall, can be pumped direct into the "flood drain." The sewage-farm is on the road leading to Thorne, on the north side of, and about two miles from, Doncaster; the corporation are owners of a considerable estate in this neighbourhood, and the "Wheatly Hills Farm," of 264 acres of land (partly light open soil and partly clay) has been laid out as a sewage-farm, and has been let with the sewage, together with a suitable house and farm buildings, on lease for 14 years, at a yearly rent of 800*l.*, the corporation undertaking to pump and deliver the sewage of Doncaster on to the farm at the yearly cost of about 300*l.* The clay-land is underdrained; but the light open land is only underdrained in the valleys and low places, and it is found that the purified drainage water finds its way readily through the light soil from long distances to these subsoil drains. There are five acres of land, especially laid out, and deep under-drained, which can be used as a filter on the "Downward Intermittent" principle, as proposed by the Rivers Pollution Commission. Up to the present time, how-

ever, the sewage has been utilised, and it has not as yet been found necessary to use the "filter" as an auxiliary to the irrigation process. The Sewage-Farm has now been in operation three years, no nuisance having arisen either at the pumping-station or on the farm. The distribution of the sewage over the land is judiciously managed, as none of it is allowed to stagnate, and thereby cause nuisance, and destroy the crop. The whole of the sewage of the night and following morning is pumped on to the farm by 11 o'clock in the forenoon, and the longest period during which the sewage is allowed to be at rest in the main outfall-sewer is between 6 p.m. and 6 a.m.

The crops grown this year (1875) to which the sewage has been applied, are: beans, 13 acres; peas, 6 acres; oats, 7 acres; barley, 35 acres; wheat, 51 acres; Italian rye grass, 35 acres; mangolds, 34 acres; swedes, 16 acres; potatoes, 8 acres; white turnips, 6 acres; hay, from permanent grass, 7 acres; permanent grass fed off, 22 acres; market garden produce, 12 acres; and there were also in fallow 8 acres.

The bean crop was a good one; the pea crop, which was partly good, and sold green, produced 10*l.* 10*s.* 0*d.* per acre; the oats were light, owing to the drought in March, April, and May; the wheat made excellent straw, but the crop was damaged by the heavy rain in June and July, and gave only an average yield; the four cuttings of Italian rye grass produced 30 tons to the acre, and sold for 16*s.* 8*d.* per ton; the mangolds were, owing to the drought and deficiency of sewage, late in starting, but as soon as the sewage was applied they grew well, but did not, however, produce more than 26 tons to the acre, and sold on the ground for 15*l.* 15*s.* 0*d.* per acre, the buyer to "pull and lead off;" the swedes also only yielded a light crop, and sold for 7*l.* 10*s.* 0*d.* per acre; the potatoes gave a good crop, and sold for 20*l.* an acre, the buyer to get and cart them off the farm; the market garden produced very excellent crops, which commanded good prices, and were highly successful, especially that portion (3 acres) planted with fruit trees, the currants being exceedingly fine.

In addition to the waterclosets in use in the borough, there are 2,553 ashpits, having privies connected with them, and 525 separate ashpits; these are emptied by scavengers employed by the corporation, at a yearly cost of 539*l.*, and 310*l.* is received for 4,400 tons of refuse removed yearly, and sold to farmers in the neighbourhood, who use it as manure.

Particulars of Machinery.

Power of Engine and Sort of Engine.
Two compound beam engines, of 35 nominal horse power each with crank and fly-wheel; slide-valves worked by eccentrics; double expansion slides on high-pressure cylinder.

Cost of Engine and Boilers complete.
5,405*l.* Cannot give engines and boilers separately.

Gallons per hour lifted.
80,000 gallons (7th April 1873).

Head.
Nett, *including* friction, 56·5 feet.

Fuel Consumed.
(Coal; inferior Barnsley, somewhat weathered in trial (7th April 1873). 107 lbs. per hour.

Diameter of Pump.
Double acting; 20 inches diameter.

Length of Stroke of Engine.
Low-pressure cylinder, 4′ 6″ stroke.
High-pressure do. 3′ 1½″ do.

Number of Strokes per Minute.
22 revolutions.

Trial of one Engine for One Week, from 23rd February 1874 to 1st March 1874.

Time of pumping, 45¾ hours.
Coal consumed, 3 tons=147 lbs. per hour of actual pumping.
Number of stoppages, 11.
Gallons pumped, 3,843,000.
Tons pumped, 17,156¼=375 tons per hour.

HARROGATE.

Population (average)	12,000
Rateable value	£50,000
Houses	1,500
Waterclosets	1,620
Cost of main sewers	£15,583
Cost of outlet works and laying out land at Jenny Plain	£1,150
Purchase of land at outlet works at Wetherby Lane	£4,484

Harrogate.—This is essentially a water-closeted town; the area of the district is about 1,300 acres. Resident population, about 8,000, augmented in the season, from the months of May to October, to about 16,000; the annual rateable value is 50,000*l.* There are 1,500 inhabited houses, and 1,620 waterclosets in the township, and very few common privies. The waterworks belong to a private company. The "Coppice" stream, a tributary of the "Oak Beck," flows through the town, and that portion of the river-channel in the town has been covered over; into this stream several of the old sewers discharge. In 1867 complaint was made by a bleacher (Mr. Wood, of Rawden, near Leeds), whose bleachfields are on the "Oak Beck," of the fouling of the stream by the sewage of the township, and proceedings at law were threatened. The Improvement Commissioners compromised the matter by paying 580*l.*, undertaking "*not to discharge any more sewage into the stream.*" In order to give effect to this agreement, they directed their surveyor to prepare plans of main sewerage works for the township; these works were, in 1869, carried out at a cost of 15,583*l.*, and to cleanse the daily and nightly volume of sewage, which is estimated at about 168,000 gallons (inclusive of about 83,000 gallons of spring water), the Improvement Commissioners obtained a lease of 47 acres of land, a stiff clay soil at Jenny Plain, one mile from the town. This land they caused to be specially laid out, and subsidence-tanks to be constructed into which the outfall-sewer should discharge, the sewage to flow from thence through stoneware pipe carriers on to the land, and the effluent water run off into the "Oak Beck." The cost of these works was 1,150*l.* In April 1869, about two months after receiving the 580*l.*,

and while the works of sewerage and irrigation were in progress, Mr. Wood commenced a suit in Chancery against the Improvement Commissioners, and in January 1875 obtained an injunction to restrain them from polluting the "Coppice" stream and "Oak Beck" with the sewage of the township. From the decree of Vice-Chancellor Bacon the Commissioners appealed, but the Lords Justices affirmed the decision of the Court below, and on application by the defendants the time for carrying out the remedial measures was extended to April 1st, 1875. In February 1875 additional intercepting sewers were commenced for diverting the sewage from the "Coppice Stream," and conveying it to the irrigation works, but it was found impossible to complete these works by the 1st of April 1875, and an application was made to the Court for a further extension of time, and it was extended to the 1st of July 1875. In June the Improvement Commissioners applied for a still further extension, but the Court refused to grant it. In April 1875, the Improvement Commissioners purchased, at a cost of 2,200*l.*, the Knox bleachfields, in the occupation of the plaintiff, Mr. Wood, subject to a lease he held for an unexpired term of four years, and on the 4th October 1875 they took on lease, for a term of 20 years, from the Ecclesiastical Commissioners, at the yearly rent of 300*l.*, a farm of 247 acres, for the purpose of further purifying the sewage. This farm (of which only 120 acres are available for sewage irrigation) is situated on the north side of the "Oak Beck," opposite to the present irrigation fields.

In December 1875, the Plaintiff applied to the Vice-Chancellor to issue an order of sequestration, this the Court did, but suspended the operation of it for two months. The Improvement Commissioners then directed their surveyor to prepare plans and estimates for a pipe sewer to intercept the effluent water from the irrigated fields and convey it into the "Oak Beck" at a point below the plaintiff's bleachfields, this having come to the knowledge of the plaintiff, he made overtures for a compromise, and after a conference with a deputation from the Improvement Commissioners he offered to withdraw from the suit, if they would pay to him the sum of 5,000*l.* and taxed costs; the Improvement Commissioners accepted his offer, but he subsequently varied it and asked for the whole of the costs "in and incidental to the suit;" this, however, the Improvement Commissioners declined to accept, and they have since directed their surveyor to continue the main outfall-sewer, by a syphon under the "Oak Beck," on to the new farm of 247 acres, and at once to lay out the land at an estimated cost of 3,216*l.*, to receive the sewage. It is hoped that the area proposed to be irrigated will be found sufficient to cleanse effectually the whole of the sewage of the district, and thus, the Commissioners will be enabled to obey the order of the Court. The cost of the suit amounted to about 3,920*l.* The subsidence-tanks are cleansed out of every three months, the deposit being mixed with the street sweepings and sold to farmers.

Upon the present sewage farm of 47 acres, there was grown, in 1875, 600 tons of Italian rye grass, and it sold for 10*s.* per ton. The cost of dealing with and distributing the sewage in 1874, including rent of land, was 282*l.* 10*s.* 5*d.*, exclusive of interest and cost of works, and the receipts for the grass were 562*l.* 11*s.* 1*d.*

The effluent water from the sewage farm was on our inspection clear and inoffensive; and the "Oak Beck," into which it flows has the external characteristics of a clean and pure stream, there being no appearances of sewage deposit on the banks or bed of the brook, and the vegetation on the margin of the stream being free from the peculiar brown fungoid growth the result of the presence of sewage.

To prevent the sewage of High Harrogate from polluting the watercourses which have their outfall in the "Nidd," the river from which the inhabitants of Knaresborough obtain their water-supply, the Improvement Commissioners have purchased, at a cost of 1,000*l.*, 13½ acres of land at Wetherby Lane, and have caused this to be laid out as irrigation ground, and the sewage of that portion of the township, estimated at 42,000 gallons daily, is utilised thereon. The cost of the outlet-works for this portion and laying out the land was 3,484*l.* The Commissioners have let the land (13½ acres) with the sewage at a yearly rent of 52*l.*, the tenant undertaking to dispose of the sewage so as not to cause a nuisance.

LEAMINGTON.

Population, including the districts of Lillington and Milverton	24,700
Rateable value of the borough	£113,400
Houses	4,500
Waterclosets	8,370
Cost of main sewers	£16,239
Cost of outfall works, pumping station, and machinery	£24,239
Volume of sewage every 24 hours, upwards of (gallons)	800,000
Yearly expense of pumping sewage	£1,035
Yearly amount received for sewage	£450

The royal borough of Leamington-Spa has an area of about 1,571 acres, a population of about 24,700, and 4,500 houses; the rateable value is 113,400*l.* Waterclosets are principally used, there being 8,370 in the town. The house refuse and ashes are removed from the ashpits by men and carts employed by the corporation, and about 3,000 cubic yards of this house-waste is collected annually, at a cost of 780*l.*, and given away to farmers, there being no sale for it. A system of sewerage works was commenced in 1859 and finished in 1861, but additions are made from time to time, the total cost of their works being 16,239*l.* The sewers are ventilated by 157 grids in the covers of the manholes, and 200 additional ventilators are at once to be put to the mains sewers. On completion of the sewerage works in 1861, the sewage, which formerly flowed direct into the river Leam, was intercepted by subsidence-reservoirs constructed near the bank of the river on the west side of the town. The costs of these reservoirs, tank, and outfall-works was 8,000*l.* The precipitation of the suspended matters of the sewage was accelerated by mixing with it as it arrived at the tank a certain proportion of the "milk" of lime, and violently agitating the sewage as it flowed from the tank on its way to the reservoirs of subsidence. In these reservoirs a large quantity of highly-putrescible mud was deposited and the supernatant liquid flowed into the river, carrying with it, especially in heavy rainfall, considerable portions of this mud. The annual expense of working the lime process was 500*l.*, and it failed to purify the sewage; the offensive state of the river became gradually intensified by the impure sewage of the town flowing into it, and eventually, after repeated complaints by Lord Warwick, Mr. Richard Heath, and Mr. W. Field, riparian owners, Mr. Richard Heath, on the 25th November 1864, filed a Bill of Complaint in the Court

of Chancery, and on the 1st June 1866, obtained an "interim injunction" to restrain the local board from polluting the river Leam with the sewage of Leamington. The local authority did not satisfy the Court that they were taking proper means to abate the nuisance, and an order of sequestration was, on the 2nd August 1867, issued, but suspended from time to time. Subsequently, in 1868, the local board caused the bed of the river to be cleansed, and paid the costs of this work, amounting to 1,500*l.*, and also the costs of the suit, 5,000*l.* About the same time Lord Warwick caused an offer to be made to the Local Board to take from them on lease for 21 years the sewage of Leamington, and pay 450*l.* a year, provided it was delivered on to the Heathcote farms, a distance of 2 miles from the town. The local board accepted the offer on the 5th April 1870, and directed a cast-iron rising main to be laid from the works to the farm and pumping works to be erected and fitted with suitable machinery capable of pumping a volume of upwards of 800,000 gallons of sewage daily on to the farm; these works were finished and the pumping of the sewage to the "Heathcote Farm" commenced on the 5th October 1871, and the entire volume, except in heavy rainfall, has been pumped daily ever since that date. The soil of the farm is a fine loam on a sub-soil of gravel; the flood-water flows by a storm outlet into the Leam. The annual cost of pumping, including labour and materials, is 1,035*l.*

While the works were in progress the A.B.C. or Native Guano Company, on the 19th October 1868, made an offer to the local board to treat, free of cost, the sewage of the town by their process; and the local board, on the 4th March 1869, accepted their offer and permitted them to use the sheds, tanks, and outfall works for that purpose on condition that the company should remove the whole of the plant, which they proposed to erect on the site of the pumping station, when required to do so. The A.B.C. Company carried out their process until October 1871, and although it removed a large portion of the suspended impurities from the sewage, it, however, only took away therefrom a small proportion of the soluble polluting matters, and the effluent sewage was very little better than that which was obtained by allowing the raw sewage to settle in subsidence-tanks without chemical treatment.

The extraction of the "sludge" and drying it, especially in hot weather, in order to convert it into a manure, was attended with a nauseous odour and caused an intolerable nuisance, an extreme annoyance to the residents of Milverton, a populous and fashionable suburb of Leamington, who made repeated complaints to the local board of the "suffering they endured day and night from the offensive smell caused by "the method adopted by the company for drying of the sewage mud."

The Sewage Farm.

The effluent water on the date of our visit to the farm, August 18th, 1875, was sufficiently purified to be admitted into the river, as not a trace of sewage could be detected in the clear and inodorous stream which flowed from the meadows into the watercourses. By the kindness of Mr. D. Tough (bailiff to the Right Honourable the Earl of Warwick), we are enabled to give a statement showing the cropping of the farm and quantity of sewage applied thereon for the past four years. Mr. Tough also sent to us the following very satisfactory account of last year's experience.

"The farm is about 370 acres, and the whole of this area except 96 acres has been irrigated with sewage. We have also supplied sewage to

Acreage and Cropping of the Earl of Warwick's Heathcote Farm, with Quantity of Sewage and Number of Dressings applied to each Crop, from 1871 to 1875.

	A.	R.	P.	1871	1872	Quantity of Sewage applied.	No. of Dressings.	1873	Quantity of Sewage applied.	No. of Dressings.	1874	Tons.		1875	Tons.	
3	12	2	10	Not in occupation	Fallow	30,109½	4	Barley and cabbage	35,737½	7	8a. 2r. 0p. I. R. grass	[illegible]	21	8a. 2r. 0p. I. R. grass	[illegible]	18
"					—	—	—	8a. 2r. 0p. I. R. grass sown in spring with corn.	23,497	5	4a. 0r. 16p. cabbage	11,054½	6	4a. 0r. 16p. fallow for cabbage	2,906¾	2
"														" cabbage	29,280	12
20, 21, 22	14	0	31	Wheat and potatoes	Cabbage, parsnips, onions, and carrots.	75,340	10	Wheat barley	—	—	8a. 0r. 0p. spring cabbage	33,098½	9	I. R. grass	158,265¾	27
"						—	—	8a. 0r. 0p. spring cabbage planted after corn crop.	2,474½	1	6a. 0r. 31p. I. R. grass	54,260¾	20	6a. 0r. 31p. fallow for mangold after grass.	28,056½	8
"						—	—		—	—	Turnips after cabbage	5,584¾	2		—	—
"						—	—		—	—	Wheat	—	—	Beans	—	—
23, 29	15	2	16	Potatoes and oats	Wheat	—	—	Potatoes and mangold	—	—	Fallow for barley	3,965½	2	I. R. grass	146,675¾	49
24	5	1	12	Wheat	Potatoes	—	—	3a. 0r. 0p. cabbage	8,857	5	Grass sown at Michaelmas	18,894½	8		—	—
"						—	—	2a. 1r. 12p. peas	—	—						
25	10	1	17	Barley	I. R. grass	104,883½	26	I. R. grass	152,317¼	29	9a. 1r. 17p. I. R. grass	113,432¼	29	9a. 1r. 17p. cabbage	32,703½	8
"						—	—		—	—	1a. 0r. 0p. cabbage plants	4,820¼	12	1a. 0r. 0p. plants	2,410¼	6
"						—	—		—	—	10a. 1r. 17p. cabbage after grass	12,294¾	3		—	—
26, 27, 62, 63	22	3	37	Permanent pasture	Permanent pasture	—	—	Permanent pasture	—	—	Permanent pasture	—	—	Permanent pasture	—	—
27, 28	13	3	3	Peas	I. R. grass	122,832½	18	I. R. grass, 4 cuttings	126,518	19	13a. 3r. 2p. savoys	15,642½	3	I. R. grass	279,010	42
"						—	—	Savoys after grass	93,830½	15	7a. 0r. 0p. cabbage, 1st cut	37,407	12		—	—
"						—	—		—	—	" " 2nd "	38,289	13		—	—
"						—	—		—	—	6a. 2r. 3p. wheat	—	—		—	—
"						—	—		—	—	Grass after cabbage and wheat, sown at Michaelmas.	24,895½	4		—	—
"						[illegible]	[illegible]	Permanent pasture	[illegible]	1	Permanent pasture	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
42	8	3	0	Mangold	Wheat	—	—	I. R. grass	52,382¼	17	I. R. grass	67,297½	20	Mangold, swedes, and carrots	—	—
43	9	0	4	Swedes	Barley	—	—		—	—	I. R. grass	121,483¼	29	Mangold and 5 acres belonging of ditto belonging to No. 42.	117,463¾	18
"						—	—		—	—		—	—		—	—
"					Grass sown at Michaelmas	16,152¼	4	I. R. grass	126,603½	31	Fallow for roots after grass	6,307	2		—	—
"						—	—		—	—		—	—	Fallow for roots (No. 43)	18,050¾	5
"				[illegible]	Wheat } Clover sown with corn.	Wheat, 32,126½	7	Clover	51,138½	7	Beans	[illegible]	[illegible]	[illegible] mas).	[illegible]	[illegible]
47	10	0	32	Barley	Oats }	45,095½	7	Clover	—	—	Wheat (grass at Michaelmas)	17,937	4	I. R. grass	166,470	36
48	11	0	36	Swedes	Wheat	—	—	I. R. grass	161,136	31	I. R. grass	103,084¾	23	Beans	—	—
"					Grass sown at Michaelmas	20,886½	4		—	—		—	—		—	—
49, 55, 56	23	2	8	Wheat	Beans	—	—	Wheat	—	—	Oats	—	—	19a. 2r. 8p. swedes and turnips	—	—
"						—	—		—	—	4a. 0r. 0p. mangold	—	—	4a. 0r. 0p. mangold	7,352	4
"				[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
51, 53	18	1	4	Wheat	Mangold	66,381½	10	Wheat	—	—	Beans	—	—	Wheat	—	—
54	9	1	29	Wheat	Beans, 4 acres sewaged	1,932½	1	Wheat	—	—	I. R. grass	119,094¾	29	I. R. grass	98,734¾	25
"						—	—	Grass sown with corn	30,407½	8		—	—		—	—
57	20	2	33	Pasture	Wheat	—	—	Beans	—	—	Wheat	—	—	Oats	—	—
58, 59	20	0	15	Peas, swedes, and turnips	Wheat	18,216¼	2	Mangold and swedes	28,779¼	4	Wheat	—	—	Beans	—	—
"						—	—		—	—	Fallow for beans	13,777½	2		—	—
60	10	1	7	Barley	Swedes	—	—	Wheat	—	—	Beans	—	—	Wheat	—	—
61	12	1	3	Barley	Swedes	—	—	Wheat	—	—	Clover	—	—	Clover	—	—
62	5	1	30	Wheat	Clover	—	—	Wheat	—	—	Barley	—	—	Potatoes	—	—
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
"						—	—		—	—	parsnips.					
"						—	—		—	—	4 acres fallow for carrots and parsnips.	4,861	3	2a. 1r. 34p. mangold	4,559¾	4
"						—	—		—	—	6a. 1r. 34p. potatoes	—	—	1a. 0r. 0p. rhubarb strawberries	—	—
52	10	3	11	I. R. grass	I. R. grass	111,384	21	Wheat	—	—	Mangold	63,529	15	Wheat	—	—
"						—	—	Fallow for mangold	27,886½	6		—	—	Fallow for mangold	9,176½	2
66	10	2	25	Barley	Clover	29,520¾	7	Wheat	—	—	Mangold	—	—	Oats	—	—
69	9	2	3	Not in occupation	Beans	—	—	6a. 0r. 0p. mangold	3,455½	2	Wheat	—	—	Barley	—	—
"						—	—	3a. 2r. 3p. fallow	—	—		—	—		—	—
71	7	2	36	Not in occupation	Swedes	3,093½	1	Wheat	—	—	Turnips	—	—	Barley	—	—
72	9	1	36	Do.	Wheat	—	—	Swedes	—	—		—	—	Clover	13,886¼	4
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Sewage supplied to farmers	704,611¼	—	Sewage supplied to farmers	[illegible]	—	[illegible]	270,133½	—	Sewage supplied to farmers	[illegible]	—
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Total for 1872	927,361		Total for 1873	[illegible]		Total for 1874	1,318,618½		Total for 1875	[illegible]	

the adjoining farmers on about 80 acres of land for which we received from 20*s.* to 30*s.* per acre. The sewage of Leamington is pumped to the farm daily, and is used in winter on fallow or grass-land, and in summer on grass, cabbage, carrots, parsnips, onions, mangolds and turnips. We never apply any sewage to the root crops, with the exception of cabbage, until May or June; but this latter crop is sewaged in the spring as soon as the weather will permit. We have tried sewage on corn crop, but found it difficult to apply it while the crop is growing, in fact sewage ought not to be applied to corn crops. The last season we had excellent crops of everything grown on the farm. The farm is worked with 13 horses which are all fed on the sewage produce and do remarkably well."

"We have also a dairy of 40 cows, the milk is sold on the farm at 11*d.* per gallon the cows are all stall fed in summer on grass, and in winter on turnips, mangolds, and hay and straw, cut into chaff, and a little artificial food. The calves are reared and sold when two or three years old; we also keep a few sheep on the farm. During the last two years we have gained 10 silver cups and a great many money prizes for roots grown by sewage."

MERTHYR TYDFIL.

Population (about) - - - - - -	55,000
Rateable value - - - - - -	£135,000
Houses - - - - - - -	10,778
Waterclosets - - - - - -	8,000
Cost of outlet sewer, purchase and laying out of land as filters, and as sewage farms - - - -	£53,330
Yearly rent of 59 acres of land held on lease - -	£298
Volume of sewage every 24 hours, about - (gallons) -	1,200,000

Privies (2,800) are cleansed at the expense of the occupiers of the houses to which they belong.

Merthyr Tydfil.—This urban sanitary district has an area of 17,714 acres, a population of about 55,000, and a rateable value of 135,000*l.* There are 10,200 inhabited and 578 uninhabited houses; connected with these are about 8,000 waterclosets and the drainage from about 2,800 privies. In 1864, the waterworks were completed, and it then became necessary to provide for the disposal of the used water which greatly augmented the volume of the sewage. Plans were prepared by Mr. S. Harpur, the engineer, to the local authority for the disposal of the sewage, and approved; the works were commenced in November 1865, but owing to the failure of the contractor, were not completed till 1868, at a cost of 28,000*l.*; the crude-sewage was then discharged into the Taff. Soon after the works were completed a Bill of Complaint was filed in the Court of Chancery by Messrs. Nixon and Company, colliery proprietors, Ynysowen, to restrain the local authority from polluting the Taff, and an interim injunction, afterwards made perpetual, was granted. In April 1869, the engineer to the local authority submitted a comprehensive scheme for disposal of the sewage by irrigation; this was sanctioned, it embraced the taking and laying out at Troedyrhiew, within the parish of Merthyr, 75 acres of land; also 60 acres of common land, and 240 acres of enclosed land in the parishes of Llanfabon and Llanwonno, at

from 8 to 11 miles from Merthyr, all in the basin of the Taff; these farms have a fine loamy soil with a gravelly soil. The outfall-works, consisting of 19,000 lineal yards of brick, timber, iron, and earthenware conduit (from 12 to 24 inches in diameter) were completed in 1873. While these works were in progress the Master of the Rolls directed that means should be adopted for mitigating the nuisance in the Taff, by separating the coarser solid particles of sewage and prevent them flowing into the river; the local authority then ordered filter-tanks to be constructed near the outfall, and caused the sewage to be filtered through a medium of furnace ashes 3 feet deep, a small quantity of cream of lime being added to the sewage before filtration; this method not having satisfied his lordship he issued an order of sequestration, and from that order the local authority appealed. The Lords Justices of Appeal in July 1870 directed Mr. J. Bailey Denton, C.E., to examine and report on the best means of preventing the nuisance complained of, and he recommended that 20 acres of the 75 acres of land at Troedyrhiew should be laid out as land filters, and used on the intermittent principle proposed by the Rivers Pollution Commission; these works were subsequently carried out under his superintendence, and worked up to early in the year 1872. The addition of lime to the sewage was then discontinued, and the land-filter-beds have since been treated as ordinary irrigation ground, and are now so used, together with 230 acres of the other portions of the land, as a sewage irrigation farm. The average dry weather flow of the sewage is 1,200,000 gallons. There are fine storm outlets into the Taff. The cost of the several works was as follows:—Outfall-sewer from Troedyrhiew to the Ynyscadudug Farm, 16,002*l.* 2*s.* 10*d.*; building subsidence tanks, 387*l.* 15*s.* 1*d.*; laying out land-filtering areas (including drainage and the carriers upon 20 acres), 4,606*l.* 12*s.* 4*d.*; forming, draining, and making carriers on the remaining 55 acres at Troedyrhiew, 1,408*l.* 6*s.* 5*d.*; purchase and laying out, draining, and fencing the common land at Navigation Farm, 4365*l.* 11*s.* 5*d.*; purchase, laying out, and draining land at Ynyscadudug Farm, 14,387*l.* 6*s.* 0*d.*; purchase of Tyrybont estate, 30 acres, at Troedyrhiew, 3,002*l.* 2*s.* 6*d.*; purchase of Park Newydd estate of 67 acres, 9,170*l.* Total, 53,329*l.* 16*s.* 7*d.*

The sewage flows by gravitation on to the farms, and the annual cost of cropping the land and applying the sewage is 2,391*l.* 5*s.* 10*d.*; to this must be added the yearly rent paid by the local authority for that portion of the land held on lease (viz.) 298*l.* The accounts of the year have not been made up, but it is feared that the receipts will not cover the expenditure. The Troedyrhiew Farm of 70 acres, of which there are about 2 acres of roads, has this year produced the following crops: Italian rye grass, 34½ acres; permanent grass, 5 acres; cabbage, 8 acres; mangolds, 6 acres; swedes, 5 acres; red wheat, 3 acres; beans, 4 acres; rhubarb, ½ acre; seed beds, 2 acres. The Navigation Farm (60 acres of common land, of which roads occupy one acre) produced Italian rye-grass, 15 acres; white oats, 35 acres; willows, 3 acres; mangolds, 1 acre; and swedes, 1 acre. Ynyscadudug Farm (93 acres only bore crops) produced hay from 83 acres of permanent grass; Italian rye grass, 4 acres; white oats, 4 acres; and swedes, 1 acre. There were very good crops of hay on the land at Ynyscadudug which realized 6*l.* per acre (the land before the sewage was applied was let at 15*s.* per acre). The Italian rye grass realised 7*l.* per acre on common land which was formerly worth 2*s.* 6*d.* per acre. The oats were sown late and only yielded a light crop. The wheat produced 25 bushels to the acre and a large quantity of fine straw. The mangolds and swedes produced each

30 tons to the acre. The Italian rye grass at Troedyrhiew was cut six times and gave an average of 6 tons per acre at each cutting, and fetched 1*l.* per ton on the farm; the pickling cabbage sold for 50*l.* per acre, and the other cabbage for 30*l.* per acre.

In addition to the sewage 30 tons of stable dung was used on the Troedyrhiew Farm, which is situate within 250 yards of the village. No complaints have been made of nuisance arising from the farm, or of the condition of the effluent water flowing into the river, as it has invariably been bright and pure. The tanks are cleaned out every fortnight, and the "sludge" is mixed with the house refuse and dug or ploughed into the land.

The inhabitants living near portions of the sewage-farms speak of them as the "gardens."

RUGBY.

Population (about)	8,400
Rateable value	£45,000
Houses	1,700
Waterclosets	1,400
Cost of outlet works and laying out farm	£5,800

This Local Board of Health district has an area of 1,617 acres, and a rateable value of 45,000*l.* The sewage of 8,400 inhabitants of Rugby, living in 1,700 houses, is disposed of in irrigation. There are 1,400 waterclosets, very few privies, and no cesspools. A system of sewerage has been carried out at a cost of 5,764*l.*; the works were commenced in 1852, and the main-outfall was into the river Avon. On completion of the works the late Mr. Walker applied to the local board to be allowed to divert the sewage from the river, and to use it on his own adjoining land, and concession having been granted to him, a reservoir was constructed, and the sewage was pumped therefrom through cast-iron pipes, laid over the entire farm, on which were fixed a number of hydrants, in suitable situations, and the sewage was distributed from thence, as required, by a flexible hose and jet.* The outlet into the Avon was then only used for storm-water, or when the application of the sewage to the land was from any cause interrupted. This mode of irrigation was carried on for some time; but as Mr. Walker did not deal with the whole of the sewage, the river became polluted, and an action at law was, in August 1855, commenced against the local authority by Mr. Charles Caldecott, of Holbrook Grange, a riparian proprietor, but a technical objection having been taken, the action was abandoned. The local board then discussed the best means of disposing of the sewage, and decided in 1857 to hire from Mr. Walker 65 acres of land, at the yearly rent of 290*l.*, including rates and taxes, to construct subsiding tanks, and to cause the farm to be laid out on the surface irrigation principle, at a cost of 5,800*l.* A volume of 400,000 gallons of sewage every 24 hours (150,000 gallons being subsoil water,) has

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* The cast-iron pipes were extended over an area much larger than could be supplied with sewage, and the cost of pumping and of irrigation by hose and jet proved to be too expensive and was consequently abandoned.

flowed continuously since that date over the land. No complaints have been made of the state of the effluent from the farm into the river. The local board at Lady-day, 1874, sublet the land hired of Mr. Walker, to Mr. J. A. Campbell, at a yearly rent of 350*l.*, the local board maintaining their right to dispose of the sewage upon the land, and paying the labour cost of the distribution. In 1871, in order to utilize the sewage of another portion of the district, the local authority hired of the rector of Rugby, about 13 acres of land, at the yearly rent of 54*l.*, and caused the sewer to be extended, and the sewage to flow on to this land; they have since sublet it, with the sewage, for 79*l.* per annum.

Mr. J. A. Campbell has kindly given to us the following information:—

Acreage of Sewage Farm under Crop, 57*a.* 0*r.* 19*p.*

Crops, 1874.

	a.	r.	p.
Wheat	21	3	22
Beans	4	2	29
Oats	8	2	2
Italian rye grass	22	0	11
Total	57	0	24

Cash produce of farm	701	11	1½
Expenses, including rent (360*l.*)	725	13	10
Balance against farm	£24	2	8½

NOTE.—See pages 86, 87, as to raw and effluent sewage.

TUNBRIDGE WELLS.

Population (about)	23,000
Rateable value	£142,914
Houses	5,750
Waterclosets	5,635
Cost of outlet works, purchases, and laying out of farms	£87,243
Volume of sewage every 24 hours	(gallons) 650,000

Tunbridge Wells, an urban sanitary district in the counties of Sussex and Kent, disposes of the sewage of its 23,000 resident inhabitants by irrigation. The district has an area of 3,352 acres, and a rateable value of 142,914*l.* 10*s.*; the town portion is drained by main sewers of irregular form constructed of brick, the branch sewers are of stoneware pipes. Waterclosets are chiefly used, the number being 5,635 in the town. The sewage was formerly allowed to run direct into the Calverley Brook.

On the 24th November 1865, an injunction was obtained by Mr. Frederick David Goldsmid of Summer Hill Park to restrain the Improvement Commissioners from polluting the "brook," and the latter having failed to satisfy the court that they had rendered the sewage inoffensive, an order of sequestration was subsequently granted; this order, however, was suspended from time to time, and finally discharged

on 2nd July 1874, on the Commissioners undertaking to intercept the sewage, and practically purify it before it flowed into the brook; to defray the expense of cleaning out the Summer Hill Lake which amounted to 744*l.* 17*s.* 8*d.*; and also to pay the costs of the suit, about 3,000*l.*

To satisfy these conditions, the Improvement Commissioners caused intercepting sewers and outfall works to be constructed, and they also purchased two farms, one of 120 acres of stiff loamy soil 1½ mile to the north, and the other of 165 acres of light open soil 3½ miles to the south of the town. These farms are prepared and laid out for irrigation, and the sewage, which is not treated by any chemical process, flows by gravitation through subsidence-tanks, and a daily volume of about 414,000 gallons is thus delivered on to an area of 118 acres at the South Farm, and about 236,000 gallons on to an area of 100 acres at the North Farm, the solid refuse is removed from the tanks when necessary and sold to farmers, who clean out the tanks, remove the deposited material, and pay 65*l.* a year for it. The effluent water from the North Farm flows into the Calverley Brook, and that from the South Farm into the Brodwater Brook, and the County Ditch, which are tributaries of the Medway. Samples of this water are collected every fortnight by the farm bailiffs, and summitted to the Sewage Outfalls Committee. No complaint has been made of the state of the effluent water since the removal of the order of sequestration. The crops produced this year were, on the

NORTH FARM.

Italian Rye Grass, 30 acres.	Pasture and Meadow, 20 acres.	Wheat, 15 acres.	Oats, 10 acres.	Beans, 9 acres.	Barley, 3 acres.	Winter Oats, 5 acres.	Mangolds, 3¾ acres.	Swede Turnips, 3 acres.	Carrots and Cabbage, 1¼ acres.
Per acre. —	Per acre. —	Per acre. —	Per acre. —	Per acre. —	Per acre. —	Per acre. —	Per acre. —	Per acre. —	Per acre. —
65 tons in five cuttings.	A heavy crop of coarse hay stacked on the farm.	5 qrs.	9 qrs.	4 qrs.	5 qrs.	9 qrs.		25 tons	—

SOUTH FARM.

Italian Rye Grass, 21 acres.	Pasture and Meadow, 30 acres.	Hops, 22 acres.	Wheat, 17 acres.	Oats, 14 acres.	Beans, 4 acres.	Mangolds, 3 acres.	Swede Turnips, 5 acres.	Clover, 2 acres.
Per acre. —	Per acre. —	Per acre. —	Per acre. —	Per acre. —	Per acre. —	Per acre. —	Per acre. —	Per acre. —
40 tons	Cut for hay or pastured.	13 cwt.	4½ tons	6 qrs.	3 qrs.	40 tons.	30 tons.	—

The cost of the sewage works (purchase of and laying out of farms, law costs and arbitration, expenses relating to purchase of farms, and compensation to tenants) has been 87,243*l.*

Northern Sewage Farm.

Profit and Loss Account for the Year ending the 25th of March 1876.

Receipts.

Dr.

	£ s. d.	£ s. d.
To sale of 11 cattle (8 steers 2 cows, and a calf - - -	213 4 6	
„ sale of 40 sheep -	113 10 0	
„ do. 2 horses -	26 0 0	
		352 14 6
„ do. rye grass -	462 3 9	
„ sale of wheat, oats, barley, peas, and beans	314 17 6	
„ sale of mangolds -	102 0 5	
„ do. milk - -	4 8 6	
„ do. manure -	83 6 6	
„ do. straw - -	15 15 5	
„ do. fagots - -	1 12 6	
„ cattle and pony keep	9 6 6	
„ garden, meadow, and cottage rents -	87 12 0	
		1,086 3 1
„ outstanding accounts		20 10 2

Austen's Valuation made to 25th March, 1876.

To 4 horses - -	205 0 0	
„ 33 store beasts -	453 0 0	
„ manures - -	87 10 0	
„ hay, straw, and roots	96 5 0	
„ corn - - -	231 15 0	
„ cultivations and young seeds - -	119 9 0	
„ implements of husbandry - - -	254 2 6	
„ man applying sewage	29 18 0	
		1,476 19 6
		£2,936 7 3

Expenditure.

Cr.

	£ s. d.	£ s. d.
By valuation on the 25th March, 1875, brought forward - -		1,251 13 0
„ purchase of 14 cattle (7 steers, 1 bull, and 6 calves) - -	80 9 0	
„ purchase of 40 sheep	84 0 0	
„ do. 2 horses	132 6 0	
		296 15 0
„ farm implements and smiths' works - -	20 17 11	
„ seeds - - -	73 18 9	
„ provender - -	59 1 7	
„ bailiff's wages -	97 9 8	
„ farm labourer -	489 11 1	
„ repairs to roads -	4 19 2	
„ do. farm buildings - - -	7 17 0	
„ rates and taxes -	44 18 2	
„ insurance - -	9 11 9	
„ miscellaneous - -	54 16 6	
		863 1 7
By outstanding accounts		52 18 2
„ balance - -		471 19 0
		£2,936 7 3

Southern Sewage Farm.

Profit and Loss Account for the Year ending the 25th of March 1876.

Receipts.

Dr.

	£ s. d.	£ s. d.
To sale of 67 cattle (44 steers, 12 heifers, and 11 calves) - -	1,110 5 3	
„ sale of 63 sheep -	160 15 10	
		1,271 1 1
„ do. rye grass -	155 18 6	
„ do. wheat and oats	204 3 0	
„ do. mangolds, &c.	61 18 0	
„ do. manure -	30 0 0	
„ do. straw - -	2 6 0	
„ do. hops (less commission, &c.) -	1,363 5 2	
„ sale of hop-pole fagots	3 0 0	
„ do. cottage rents -	49 9 0	
		1,869 19 8
„ outstanding accounts	83 3 7	
„ do. stock, 12 sheep sold to E. Carey	31 4 0	
		114 7 7

Austen's Valuation made to 25th March, 1876.

To 7 horses -	379 0 0	
„ 27 store beasts	534 0 0	
„ 12 sheep	32 8 0	
„ manures -	71 8 0	
„ hay and straw -	32 10 0	
„ corn - - -	176 15 0	
„ cultivations and young seeds -	112 10 0	
„ hop-poles, manure, and labour - -	505 0 0	
„ implements of husbandry - - -	234 2 6	
„ man applying sewage	29 18 0	
		2,007 11 6
		£5,262 19 10

Expenditure.

Cr.

	£ s. d.	£ s. d.
By valuation on the 25th March, 1875, brought forward - -		2,370 0 9
„ purchase of 65 cattle (47 steers, 11 cows, and 7 calves) - -	727 11 0	
„ purchase of 76 sheep	154 13 0	
„ do. 1 horse	55 0 0	
		937 4 0
„ farm implements and smiths' work - -	41 13 7	
„ seeds - - -	64 2 7	
„ provender - -	132 16 1	
„ hop-poles - -	146 13 0	
„ hop sets - -	1 7 0	
„ artificial manures -	41 3 0	
„ bailiff's wages -	134 6 8	
„ farm labourer -	424 18 4	
„ labour on hops -	450 8 6	
„ rates and taxes -	112 10 4	
„ insurance - - -	8 1 6	
„ repairs to farm buildings - - - -	33 1 0	
„ hop pocketing -	56 14 5	
„ coal and lime -	13 4 6	
„ miscellaneous -	61 17 11	
		1,722 18 5
„ outstanding accounts		176 9 0
„ balance - -		56 7 8
		£5,262 19 10

WARWICK.

Area (acres)	
Population (about)	11,000
Rateable value	£43,339
Houses	2,400
Waterclosets	2,000
Cost of main sewers	£6,400
Cost of outlet works, pumping station, and laying out farm	£10,085
Volume of sewage every 24 hours (gallons)	700,000

This borough has a rateable value of 43,339*l.*, and a population of about 11,000 residing in 2,400 houses to which are attached 2,000 waterclosets; there are very few privies. Sewerage works were commenced in 1856 and finished in 1857, at a cost of 6,400*l.*, and the sewage then flowed by two main outfalls into the Avon. The river soon became badly polluted and the riparian proprietors, Miss Ryland, Mr. Edward Greenway, M.P., and Mr. John Staunton, complained of the nuisance and threatened proceedings to compel the corporation to abate it. The outfall sewers were, in 1869, extended to a farm on the Stratford Road about 1¼ miles from the town. This farm of 135 acres, of stiff clay land, was taken on lease for 21 years at a yearly rent, for the first five years, of 40*l.*, and for the remainder 16 years of the term at 47*l.* 10*s.* The corporation directed the farm to be laid out to receive the sewage, and a volume estimated at 700,000 gallons (one third being subsoil water) has been pumped every 24 hours to a height of 64 feet and distributed in irrigation over the land. The old sewers have been made available as conduits for surface water with outlets direct into the river. The sewers are being ventilated by pipes with swan-neck tops carried up near to the surface of the streets into small detritus pits covered over with iron grids. The outlet sewage works, including engines, pumps, and pumping-main and laying out the farm cost 10,084*l.* 18*s.* 1*d.* The working expenses are 572*l.* 11*s.* 6*d.* per annum. From 1869 to September 1875 the corporation worked the farm, but have since leased it to a limited company for 21 years at the annual rent of 47*l.* 10*s.*, and have assigned as reasons for so doing that there is an annual loss on the farm, that the corporation have had no capital to properly carry it on, and that the working expenses are taken out of the general district rate.

During the 12 months ended September 1875, the farm has been cropped with oats, 5 statute acres, swedes 6 acres, mangolds 15 acres, beans 3 acres, celery, cabbage and potatoes 4 acres, Italian rye grass 39 acres, and permanent grass 49 acres; besides these crops there was in fallow and roads an area of about 14 acres. The oats produced a very fair crop; the swedes were good and gave about 20 tons to the acre. The mangolds were a fair average crop of about 40 tons to the acre. Some of the Italian rye grass was excellent, especially that grown on the land which had been drained, this being cut six times. There was also a very good crop of hay got off the permanent pasture; the company propose to stock the farm and to under-drain the whole of it; the drains will be 12 feet apart, and at depths varying from 3 feet 6 inches to four feet; they also propose to erect suitable farm buildings.

The expenditure on the sewage-farm for 1873, including rent, labour, &c. was 1,369*l.* 6*s.*, and the receipts from the sale of the produce was 907*l.* 6*s.* 10½*d*; whilst in 1874 the expenditure was 1,494*l.* 18*s.* 8*d.*, and the receipts were 1,071*l.* 10*s.* 4*d.*

Note.—See page 89 as to raw and effluent sewage.

WEST DERBY.

Public Offices, Stoneycroft, near Liverpool.
24th April 1876.

We now furnish the information asked for in letter of the 31st ultimo as to this Board's sewage farm, &c.

For the sake of convenience we have set out the inquiries below, and against them have placed the answers seriatim :—

Area in acres of land used and to be used for the utilization and purification of the sewage of the district.	207 statute acres. A plan is sent herewith.
1. If purchased, the cost ?	The *nett* amount paid owners for the land has been 30,325*l.* 2*s.* 0*d.* The total amount paid for tenants' compensation and for the costs of the owners and tenants is 3,916*l.* 1*s.* 9*d.*, or about 166*l.* per acre.
2. If leased, the terms and rental ?	
3. The cost of preparing the land ?	The *nett* amount paid for "laying out" the land only has been 8,934*l.* 9*s.* 8*d.*, which includes wages, piece work, drain tiles and pipes ; carting tiles and rock for roads ; timber, lime, cement, cinders, horse keep, and such like, or about 43*l.* per acre.
4. The estimated annual working costs ?	For the year ending 25th March 1875 (the last year for which the accounts have been audited), the cost of cropping, cultivating, and applying sewage was 2,334*l.* 15*s.* 3*d.* This amount does *not* include the instalments of the loan and the interest.
5. The daily volume of sewage in gallons to be applied ?	At 30 gallons per head per day. Population into eastern and western sewers, 24,100=723,000 gallons per day. Remainder of population, 7,300, goes into corporation sewers.
6. The local population ? -	The population, whose sewage is already applied to the farm, is 18,600 persons ; the sewage of 5,500 more persons will shortly be diverted into the tanks which are now being constructed at the farm, and are almost completed, and will thence be pumped on to the farm land. The sewage of the remainder of the population of the district, viz., 7,300 persons, passes into the sewers of the corporation of Liverpool.
7. The number of water-closets in use ?	3,000 in western area, and 220 in eastern area. This is exclusive of waterclosets draining into corporation sewers.
8. The number of privies and ashpits ?	In western area about 1,042 middens, and in eastern area about 591 middens. In the majority of cases there are two privies to each midden. This is exclusive of those in corporation area.

9. The annual cost of cleansing these?	700*l.* a year. The work is done by a contractor. This includes those in corporation area.
10. The weight in tons of the refuse?	The probable weight from middens and dry ashpits to be removed per annum is about 17,000 tons in the whole of the district.
11. The price per ton obtained if sold?	The refuse is the property of the contractor.
12. The total cost of the works and land and preparation of this land for use as a sewage farm is required?	To 24th March 1876, 61,873*l.* 5*s.* 9*d.*, which includes the items referred to in answers to the first and third queries; the surveying, engineering, and legal expenses, and all other costs and expenses. The amount estimated still to be expended to wholly complete the works at the farm is 1,476*l.* 14*s.* 3*d.*, making the total cost 63,350*l.* 0*s.* 0*d.*
13. The annual cost of working the Sewage Farm?	See answer to query No. 4 above.
14. The estimated income to be obtained from the Sewage Farm?	The total income of every description for the year ending 25th March 1875 (the last year for which the accounts have been audited) was 3,349*l.* 10*s.* 10*d.*
15. Is the land yet in use as a sewage farm, and, if so, what crops have been grown, and what did they sell for?	Yes, and all but 30 acres has had sewage applied to it. In the year ending 25th March 1875, the crops and the amounts they realized, being the produce of the farm, were as follows:—

	£	*s.*	*d.*
Rye grass	1,135	17	4
Vetches	26	10	8
Mangel wurzel	228	16	2
Turnips	106	17	8
Carrots	121	9	7
Peas	334	4	5
Barley	55	17	0
Oats	63	0	3
Cabbages and savoys	109	15	7
*Potatoes	351	15	7
*Willows	12	10	8
Total	£2,546	14	11

* The land on which the potatoes and part of the willows were grown has had no sewage applied to it.

(Signed) RADCLIFFE AND LAYTON,
Clerks to the Board.

NOTE.—This farm had not been brought fully into operation when this return was made.

APPENDIX No. II.
FILTRATION.

KENDAL.

Area (acres)	410
Population, about	13,700
Annual rateable value	£44,600
Houses	2,727
Waterclosets	450
Sewerage works, cost	£18,000
Sewage farm, cost	£16,371
Repairs to buildings, cost	£700
Laying out of filter beds on farm (cost)	£1,400
Cost, yearly, of disposing of sewage	£110
Receipts for corps and grazing	£495
Volume of sewage every 24 hours (gallons)	750,000

Kendal, an ancient market town and modern borough of about 13,700 inhabitants in Westmoreland, 262 miles north-west by north from London, is situate on the banks of the river Kent, and on the borders of the Lake district; it has a moist climate, the local rainfall being about the heaviest throughout the year of any town in England, ranging from 60 to 80 inches. Woollen cloth has been manufactured from the time of the reign of Edward III. There are at present large woollen manufactories, common Brussels and Kidderminster carpets, large tannaries, paper mills, and marble works. The waste and polluted water from these several works is now diverted from the river by the new intercepting sewers.

This borough has adopted the process suggested by the Rivers Pollution Commission (*i.e.*) "*downward intermittent land filtration*," combined with irrigation, adapted to cleanse the filthy sewage produced by 13,700 inhabitants and the liquids polluted by manufacturers. The borough has an area of 410 acres and a rateable value of 44,600*l.* A system of sewerage was carried out between the years 1868 and 1872 at a cost of 18,000*l.* Connected with this system there are 2,727 houses, 450 waterclosets, and the overflow from about 1,600 common privies. The sewage flows by gravitation to the "Wattsfield Estate," an area of 66 statute acres, which the local authority purchased for 16,371*l.*, about 248*l.* per acre. Subsidence-tanks were built at the outfall of the main-sewer into which sewage is discharged, and from thence flows over 16 acres of the land which had been levelled at a cost of 400*l.*, or 25*l.* per acre. The area so prepared has, however, been found to be insufficient to purify the sewage, the effluent flowing from the land into the river having caused a nuisance, which was complained of by Captain Braithwaite Wilson and other riparian owners. The local authority then called in Mr. J. Bailey Denton, who advised that the whole of the 16 acres should be laid out as land-filter-beds at a cost of 1,000*l.*, or upwards of 60*l.* per acre. The Board did not, however, consider that the work could be done for that sum, and directed that 5 acres only be so laid out, and this area has cost 1,400*l.*, or 280*l.* per acre. A volume of sewage every 24 hours of about 750,000 gallons (of which about 350,000 gallons is subsoil water from springs tapped during the execution of the sewerage works) has flowed continuously on to the 5 acres of land-filter-beds, and occasionally, as required, on to the remaining 11 acres of land. This small area clarifies the sewage so as not to be a nuisance; but in practise it is found too limited for crops to be successfully grown upon it, and, therefore, the corporation have caused an additional area of 5 acres to be prepared for the reception of the sewage, and it is believed that upon the 10 acres of filter-beds not only will the foul waste of the

inhabitants and refuse from manufactures and dye works be properly cleansed, but that sufficient crops will be grown upon the land-filter-beds to pay the annual expenses of thus utilizing the sewage. During the year 1875, there has been grown on the present land-filter-beds (5 acres) cabbage, mangolds, carrots, celery, and rhubarb, which sold for 100*l.*, on the other 5 acres oats, vetches, and Italian rye-grass, which realised 75*l.*, and on the remaining 6 acres a good crop of hay which sold for 45*l.*, and this plot has been fed off since the hay was got. The yearly costs of applying the sewage to the 16 acres is 110*l.*, including 35*l.*, the cost of cleaning the subsidence-tanks. The remaining portion of the farm, to which the sewage is not applied, has farm buildings upon it and the corporation spent last year in the repairs to these buildings 700*l.*; this land is let out as grazing ground and produces 275*l.* yearly.

The soil of the farm is a very fine sandy loam upon a subsoil of gravel, and the effluent water filtering through this into the river is bright and clear. The cleansing of privies is not done by the local board, but by and at the cost of the occupier, and the refuse is sold to farmers.

APPENDIX No. III.

PRECIPITATION, CHEMICAL, AND MECHANICAL PROCESSES.

BIRMINGHAM.

Area	(acres)	8,420
Population about		350,000
Rateable value		£1,229,844
Inhabited houses		83,420
Waterclosets, about		8,000
Value of sewage, every 24 hours (gallons)		12,000,000
Privies "old system"		35,000
Privies "pail system"		7,000
Ashpits		25,000
Yearly cost of cleansing privies for 1875		£35,180
Refuse (128,512 tons) sells for		£5,885

The borough has been sewered at a cost of about 250,000*l.*, the sewage gravitating to a point at SALTLEY. In the first instance it was discharged direct into the river Tame, a small stream, which at a few miles from the works flowed through the estates of Sir Charles Bowyer Adderley, K.C.M.G., M.P. He complained of the nuisance caused in the river by the sewage, and in 1858, on his application, an injunction was granted by the Court of Chancery to restrain the corporation from discharging sewage into the Tame, but the Court granted time in which the corporation were to construct works to abate the nuisance. The corporation caused subsidence-tanks to be constructed near the main sewers outfall and the sewage to be diverted from the river; processes of sand-filtration, and also of upward-filtration were tried but were abandoned.

In 1861, the corporation purchased, at a cost of 8,000*l.*, 28¼ acres of land in order to obtain access to canal and railway, and for affording additional facilities for dealing with the mud arrested in the tanks. In 1866, Sir Charles Adderley again complained of the state of the river, and the corporation, in 1867, took on lease 128 acres of land in addition, at a yearly rent of 855*l.* with the object of cleansing a portion of the sewage by irrigation. They caused this farm to be levelled, laid out, and drained, and the necessary roads and bridges constructed at a cost of 11,250*l.*, or at a rate of 75*l.* per acre, but, in 1870 Sir Charles

Adderley again invoked the aid of the Court of Chancery, and obtained an order of sequestration.

About the same date certain other owners of property near the subsidence-tanks also moved the Court to hinder the corporation from depositing on the ground sewage-sludge arrested in the tanks and the Court, in this case also, granted the injunction prayed for. Whereupon the council either removed the sludge or dug it into a portion of the farm-lands. Thus restrained on all sides, instructions were given to the borough surveyor, early in 1871, to submit surveys and levels of any lands he considered most suitable for dealing with the sewage by irrigation, and to employ such assistance as he considered necessary. In June of that year a comprehensive report was jointly prepared by Messrs. Blackburn, J. Chalmers Morton, Lawson, and Mansergh, and Doctors Voelcker and Hill, recommending the taking 2,000 to 2,500 acres of land near Kingsbury, about eight miles below the present outlet, and the construction of sewage-conduits for conveying the sewage thereto. This report was laid before the council, but the scheme being considered too costly, a special committee was instructed to again consider the whole question of sewage disposal, and acting on their advice the corporation promoted a Bill in Parliament in session 1872 to acquire powers to extend the main-sewer to a portion of the land before described at Kingsbury, and there to obtain 800 acres, on which to purify the whole of the sewage, partly by intermittent downward filtration, and partly by irrigation. The Bill passed through committee of the Commons after a lengthy opposition, but was thrown out on the third reading. The costs incurred to the corporation in promoting this Bill amounted to 10,644*l.* 7*s.* 10*d.*, and not having passed placed the town in a dilemma; however, in order to satisfy the requirements of the Court of Chancery, the corporation purchased 24 acres of land, formerly held on lease, for the sum of 8,000*l.* and subsequently further increased the area of the farm at Saltley by adding to it a purchase of 101 acres, at a cost of 29,400*l.*; acting on the advice of Thomas Hawkesley, Esq., C.E., as to the best method of treating the sewage at the outlet-works (under their limited powers). The town council, in accordance with his recommendations, caused four additional sets of subsidence-tanks to be constructed, and the sewage to be treated by the lime process. A volume of about 12,000,000 gallons every 24 hours is thus, by the addition of 13 tons of lime, to a certain extent clarified and an average of 365 cubic yards, or about 300 tons of the suspended matters of sewage, are deposited in the tanks, or about 110,000 tons per annum. The total cost of the outlet works and tanks has been 58,880*l.* The corporation have permitted Major-General Scott, C.B., R.E., to carry on experimentally his process for treating sewage and converting the "sludge" into cement, but this has not been done to any great extent, because it is not remunerative. The corporation are now making arrangements for carrying the water, clarified by the lime process on to the adjoining lands at Saltley for irrigation and filtration, and it is expected that by these means a more complete purification of the polluted liquid will be effected.

The "sludge," amounting to 365 cubic yards daily from the subsidence tanks, is removed and dug into land, a portion of the farm, at a cost of 14*l.* 10*s.* per acre, at a rate of about one acre per week, or, in the whole, 56 acres during the year. With reference to the suit instituted by Sir Charles B. Adderley, it was in 1875 arranged that the order of sequestration should be discharged, and that the injunction should be varied so as admit of the corporation constructing new sewers within the town which they had been prevented doing for some years, as also that the sum of 6,000*l.* should be paid to Sir Charles Adderley in settlement of

damages, costs, and all claims to the date of order; and that all proceedings in the cause should be stayed for five years from the date of order, on the corporation undertaking "not to construct new sewers too quickly."

The liquid sewage only represents a portion of the fæcal waste of the inhabitants, as a considerable portion of the solid excrement, mixed with urine and ashes, is received into the 35,000 old privies and 25,000 ash-pits. There are also the 7,000 privies constructed on the "pail system," distributed over the borough, and the contents of these receptacles have to be dealt with by the scavenger, and last year (1875) 128,512 tons of this refuse were removed and sent to country depôts to be afterwards disposed of to farmers. Statements of income and expenditure on sewage farm, outlet and interception works, also on Major-General Scott's cement process, and further on the collection and disposal of excreta and house waste and ashes for the year 1875, and an approximate estimate for these services for the present year are given below, together with results of analysis of a sample of the effluent water flowing to the farm during March 1875.

INCOME and EXPENDITURE for the year 1875.

INCOME.	£	s.	d.	EXPENDITURE.	£	s.	d.
Interception Department:				Interception Department:			
Amount received for contents of privies and "pails" -	5,885	0	0	Expense of cleansing and removing contents of privies and "pails" -	35,180	0	0
Outlet Department:				Outlet Department:			
Amount received for sale of a portion of sludge -	202	10	0	Expense of cleansing tanks, removing and disposing sludge -	12,778	0	0
Major-General Scott's cement process -	179	0	0	Major-General Scott's cement process -	332	0	0
Farm produce sold -	2,130	0	0	Working expense of farm	2,547	0	0

Borough Surveyor's Office, Birmingham,
January 24th, 1876.

ESTIMATES of INCOME and EXPENDITURE for the year 1876.

INCOME.	£	s.	d.	EXPENDITURE.	£	s.	d.
Interception Department:				Interception Department:			
Amount received for the contents of privies and "pails" -	7,000	0	0	Expense of cleansing and removing contents of privies and "pails" -	36,190	0	0
Outlet Department:				Outlet Department:			
Amount received for sale of a portion of sludge -	200	0	0	Expense of cleansing sludge-tanks, removing and disposing sludge -	12,825	0	0
Major-General Scott's cement process -	150	0	0	Major-General Scott's cement process -	300	0	0
Farm produce sold -	2,550	0	0	Working expenses of farm	2,960	0	0

Borough Surveyor's Office, Birmingham,
January 24th, 1876.

Chemical Laboratory, Corporation Sewage Works, Birmingham.—Certificate—Sample of effluent water from new precipitating tanks at above, taken March 1875.—Examined for general impurities.—Copy; January 26th 1876.

	Grains per Imperial gallon.
Total solid residue containing	58·10
Mineral matter	57·10
Volatile matter	7·00
Suspended matter	1·68
Soluble matter	49·42
Silica	0·84
Alumina, oxide of iron, and phosphates	0·14
Lime	12·22
Sulphuric acid	17·38
Chlorine	9·52
Free ammonia	1·218
Albuminoid ammonia	0·042
=disintegrated animal refuse	0·420
Appearance	Clear.
Smell	Slightly ammoniacal
Action on test paper	Alkaline.

Owing to the construction of new tanks and other works, as well as the large area of land used for digging in the "sludge," the farm is much sacrificed. The valley, too, in which it is situated is an excessively cold one, consequently market gardening does not answer, the crops being late. Italian-rye-grass has been found to yield the best result; but the demand for this produce has not been large.

Notwithstanding the expense incurred by the corporation in clarifying their sewage prior to its discharge into the river Tame, the sewage of adjacent townships, with large and rapidly increasing populations, is being poured daily into the Tame, or into its tributaries, without any attempt at clarification. Recently the Council have convened a meeting of representatives of adjacent boards, and at such meeting it was determined to appoint a joint committee to consider and report with reference to the formation of a combined drainage district.

BOLTON-LE-MOORS.

The borough of Bolton has a rateable value of 311,563*l.* and a population of about 93,100, inhabiting 18,249 houses, which are spread over an area of 2,002 acres. There are only about 758 waterclosets, and the fæcal matters of the population are chiefly disposed of by the 10,380 "middens," and 700 privies on the "pail" system. The "middens" are drained into the sewers, consequently no inconsiderable portion of the solid excrement, partly in solution and partly in suspension, drains into the sewerage system. The borough has been sewered, but the whole of the sewage has not been intercepted, as four of the principal connexions between the main-sewers on each side of the Croal have yet to be made. The cost of the works up to this date (January 1876)

has been about 70,000*l*. The rainfall from the roofs of buildings and surface of streets ordinarily flows into the sewers, but in heavy storms the flood water is discharged by 18 storm-outlets direct into the river.

Before any intercepting sewers were constructed, the sewage flowed by about 100 outlets direct into the river, causing a nuisance and serious annoyance to the inhabitants living adjacent and near to the Mill Lodge of the Springfield paper-works. A memorial having been presented to Mr. Secretary Bruce by the owners and occupiers of property (being ratepayers) in the township of Bolton, he directed an inquiry, under the 29th and 30th Victoria, chapter 90, section 49, "as to the "alleged default of the corporation of Bolton in not having provided its "district with proper sewers, and polluting the river Croal." This inquiry was held on 19th August 1868 by Mr. Arnold Taylor, one of the inspectors of the Local Government Act Office. On receipt of his report, dated 17th December 1868, the Secretary of State directed that a copy of it should be sent to the corporation. After the lapse of nearly a year, no decisive steps having been taken in the meantime to abate the nuisance complained of, the Secretary of State directed (28th June 1869) that the plans and estimates of the borough engineer of Bolton (Mr. J. Baylis), in reference to the diversion of the sewage of the borough from the river Croal, together with any alternative plans that may have been prepared by instructions of the town council be sent to the Local Government Act Office for approval without further delay. These plans and estimates were submitted and approved, but a further delay having taken place in carrying out the works, the Secretary of State, being satisfied that the town council had been guilty of default, issued an order under his hand the 21st day of July 1869, directing that the works necessary for the diversion of the sewage should be commenced within 14 days from the date of the order, and that the works so commenced should be continued without intermission until completion. The intercepting sewers which have been constructed have cost 10,286*l*. In June 1870 the corporation entered into an agreement with the "A. B. C. (Native Guano Company)," whereby they contracted to erect works at Burden, near the southern boundary of the borough, at a cost of 16,578*l*., and the company, on their part, undertook to defæcate and purify the sewage, so as to render it fit to be admitted into the river; and in consideration for the use of the patents of the company, the corporation agreed to pay the working expenses of the process, and to deliver to the company one-fourth part of the manure manufactured at the works from the sewage-sludge. The volume of sewage which flows to the works every 24 hours is about 2,500,000 gallons; but, in addition to this, there is a further volume of 1,000,000 gallons also intercepted, which is at present discharged by one outlet into the river, as the four syphons under the river to connect this sewer with the main outfall are not finished. There is also an additional volume of about 500,000 gallons of sewage yet to be intercepted, which now passes by several outlets direct into the river.

The A. B. C. process was carried on up to June 1873, but was then abandoned, owing to the great expense of working it, and also because the manure manufactured from the sludge could not be sold.

We were furnished by the manager of the works (27th January 1876) with the cost of labour and materials required to treat 1,035,000 gallons (about half the present daily flow of the sewage of Bolton,) for a period of 57½ hours by the A. B. C. process, *i.e.*)

	£	s.	d.
Manager (Mr. Graham). Salary -	2	17	3½
Engine driver. (Wages.) - -	1	10	0
Alum preparer. Do. - - -	1	4	0
Mixture grinder. Do. - - -	1	2	0
4 Labourers, each 1*l.* 1*s.* 0*d.* (Wages) -	4	4	0
Watchman on Sunday - - -	0	2	0
Extra for overtime - - -	0	8	0
71 cwt. of sulphate of alumina, at 1*s.* 8½*d.* per cwt. - - - -	6	1	4
132 cwt. of clay, at 4*s.* per ton - -	1	6	2
81 cwt. of carbon (waste product of prussiate of potash manufacture) - -	1	4	3½
Blood - - - - -	0	1	0
8 tons of engine coal, 7*s.* 6*d.* per ton -	3	0	0
Oil, tallow, packing, &c. - - -	0	6	0
Water and gas - - - -	0	12	0
	£23	18	1

To this amount must be added contingencies and the cost of repairs to and deprecation of works and plant. (See also special report on this process by the Rivers Pollution Commission, 1870). The corporation have not been required (up to this date 27th January 1876) to deliver any manure to the order of the patentees, but there is, and has been for the last two years, stored at the works awaiting the order of the company 700 tons of this manure. The sewage is now only treated from 8 a.m. to 6 p.m. on week days and not at all on Sundays, and the whole of the sewage from 6 p.m. to 8 a.m. flows on Sundays untreated direct into the river. The process now used is also a patent one, known as the M. and C. method, and it was stated to us to be identical with the process of Mr. Goodall, which had been tried at Leeds. In carrying out the M. and C. process there is added to the sewage to be purified a mixture consisting of the following ingredients: lime, carbon (a waste product of the prussiate of potash manufacture), house ashes, soda, and per-chloride of iron. The materials are mixed in a "pit" and lifted therefrom by means of a dredger into a second mixing pit, from which the mixture is discharged slowly into the sewage as it flows through the works into two depositing tanks, each divided into three compartments, after which the treated sewage flows for a short distance along an open conduit and thence into the River Croal. The tanks are cleaned out every fortnight, and about 70 tons of "sludge" are removed therefrom and thrown into heaps at the side of the tanks to part with the moisture which it contains, but it has been found impossible to dry it without applying artificial heat. The cost of working the M. and C. process is stated by the manager to be less than that of the A. B. C. process, and we here append the statement which he supplied to us:

"To the chairman and members of the Bolton Corporation Investigation Committee.

"Bolton Corporation Sewage Works,
January 14th, 1875.

GENTLEMEN,

I BEG to submit to you a statement of the cost for labour and materials required for the treatment of 2,500,000 gallons daily of sewage-water for a period of 57½ hours, (*i.e.*, 10 hours for five days, and 7½ hours for one day in the week."

Cost of treating Sewage by the M. and C. process.

	£	s.	d.
Wages, &c. per week	2	14	0
One labourer, preparing mixture, &c.	1	6	0
Two „ at 1*l.* 2*s.* each	2	4	0
Two „ at 1*l.* 1*s.* do.	2	2	0
Extra for overtime	0	5	0
Lime, 7 tons 3 cwt., at 18*s.* 6*d.* per ton	6	12	3
Refuse carbon, 2 tons 15 cwts., at 6*s.* per ton	0	16	6
Salts, &c.	0	15	0
Coal, 5 tons at 7*s.* 6*d.*	1	17	6
Oil tallow packing, &c.	0	5	0
Water and gas	0	10	0
	£19	7	3"

It will be observed that this volume of 2,500,000 gallons of sewage is the daily flow to the works, and that when the intercepting sewers are completed, the volume will be augmented to about 5,000,000 gallons, and as the works have been constructed for treating only 3,000,000 gallons a day of 10 hours, they will have to be considerably enlarged.

In February and April 1873, the corporation sold to Mr. John Higginbotham of Manchester, 50 tons of the manure manufactured by the A. B. C. process at 55*s.* per ton, but the persons to whom he afterwards sold it, complained of the quality of it, and he refused to pay for it, and the corporation had to commence proceedings against him to recover the amount.

The sewers in the town are ventilated by open grids in the manhole covers and also by 228 separate shafts carried up from the sewers to the surface of the streets and covered by open grids.

Besides the yearly cost of dealing with the present limited volume of liquid sewage, there is the further expense of cleansing the 10,380 "middens," the 700 privies on the "pail" system, and the yearly cost of this is 6,645*l.*, but this is not all loss as the corporation receive for 51,290 tons of refuse removed from these receptacles, 4,494*l.*

The corporation in order to get rid of the sludge caused some of it to be mixed with the refuse from the middens, and have sold 100 tons of this mixture at 1*s.* per ton. There is, however, about 2,500 tons of the prepared sludge now lying at the works.

The M. and C. process, like its twin the A. B. C. process, merely removes the grosser parts of the suspended matters in sewage, but fails to remove the putrescible organic matters in solution, and therefore the clarified sewage cannot be admitted into rivers without causing pollution, this is conclusively proved by the following result of analysis of a sample of the effluent water by Dr. Henry E. Roscoe, F.R.S., Professor of Chemistry, the Owens' College, Manchester, which has been furnished to us by the town clerk.

The Owens' College, Manchester,
To the Town Clerk of Bolton. January 22nd, 1874.

SIR,

"I BEG herewith to send you results of careful analysis (1) of effluent water and (2) of manure, sent from the sewage department of the borough of Bolton by Mr. John Forster on the 27th of December last."

(1) Effluent Water.

	Grains per gallon.	Parts per 100,000.
Total residue	62·65	89·5
Loss on ignition	5·25	7·5
Nitrogen as nitrites and nitrates	0·23	0·3292
Free ammonia	1·75	2·5
Albumenoid ammonia	0·448	0·64
Chlorine	4·20	6·00
Temporary hardness	16·2°	—
Permanent „	20·0°	—
Total „	36·2°	—

" As regards the results of this analysis it appears that the water, as compared with London sewage, contains about half as much animal refuse or products of animal decomposition. As regards the inorganic portion, this water contains considerably more than the London sewage does. These animal impurities are not completely got rid of by oxidation: and, on keeping, the water has a putrescent smell, it cannot therefore be said that the process, whatever it may be that the sewage has undergone, has done much to render the effluent water innocuous."

(2) The Manure.

Total nitrogen	0·76%
Insoluble phosphate	0·93%
Soluble phosphate	None.
Moisture	26·67%
Loss on ignition	49·80%

" From the preceding analysis of the manure in which I have only determined the constituents of importance, it will be seen that the quantity of total nitrogen and phosphates is so small that the value of the manure is certainly not greater than 1*l.* per ton.

" I am &c.,

" (Signed) Henry E. Roscoe.

" To the Town Clerk, Bolton-le-Moors."

We collected a sample of the sludge of the M. and C. process, and caused it to be analysed by Dr. A. Voelcker, F.R.S.

Results of analysis of sample of the sludge from the M. and C. process carried out at Bolton-le-Moors.

This sludge in the condition in which it was received by me contained in 100 parts—

Water		60·83
*Organic matter		14·66
Oxide of iron and alumina		3·81
Tribasic phosphate of lime		0·69
Carbonate of lime		8·18
Sulphate of lime		0·59
Alkaline salts, magnesia		1·70
Containing potash	0·30	
and chloride of sodium	0·04	
Insoluble siliceous matter (sand and clay)		9·54
		100·00

* Containing nitrogen 0·41
Equal to ammonia 0·49

In the sample of Bolton sludge there is in a ton :	s.	d.
15½ lbs of phosphates, which at 1*d.* per lb. are worth - -	1	3½
6 7/10 lbs. of potash „ 2*d.* „ - -	1	1
Nitrogen equal to 11 lbs. of ammonia which, calculating ammonia at 8*d.* per lb., is worth - - - -	7	4
Total estimated money value of 1 ton of Bolton sludge - -	9	8½

If the sludge were dried sufficiently to leave only 15 per cent. of moisture in the material it would have the following composition :

Moisture - - - - -		15·00
*Organic matter - - - - -		31·82
Oxide of iron and alumina - - -		8·52
Tribasic phosphate of lime - - -		1·49
Carbonate of lime - - - -		17·75
Sulphate of lime - - - -		1·27
Alkaline salts and magnesia - - -		3·68
Containing potash - -	0·64	
and chloride of sodium - -	0·08	
Insoluble siliceous matter - - -		20·47
		100·00
*Containing nitrogen - - -	0·89	
Equal to ammonia - - -	1·08	

A ton of Bolton sludge dried to that extent contains :	£	s.	d.
33 lbs. of phosphate of lime, worth at 1*d.* per lb. - -	0	2	9
14 lbs. of potash „ 2*d.* „ - -	0	2	4
Nitrogen equal to 24 lbs. of ammonia, at 8*d.* per lb. -	0	16	0
Total estimated money value of 1 ton of dried Bolton sludge	£1	1	1

For selling value, see page lxiii.

The cost to dry the sludge is not given ; but experience indicates that the money expended would be wasted, as dried sand and earthy material has no greater value than when wet. There is less weight to cart and that is all.

BRADFORD.

Area - - - - - -	(acres)	7,221
Population, about - - - - -		173,723
Rateable value - - - - -		£745,671
Sewerage works cost - - - - -		£70,000
Sewage defæcation works cost -		£60,000
Waterclosets about - - - -		4,050
Daily dry weather volume of sewage -	(gallons)	8,000,000
The cost of defæcating sewage (1875) -		£8,000
Privies - - - - - -		11,500
Ashpits - - - - - -		16,500
Yearly cost of cleansing privies and ashpits -		£8,000
Quantity of refuse removed yearly - - -	(tons)	56,200
First cost of railway waggons for conveying refuse -		£4,800

The borough of Bradford has been sewered at a cost of 70,000*l.*, and the 4,050 waterclosets and 11,500 privies and cesspits used by its 173,723 inhabitants are drained into the system which comprises about 48 miles of main and tributary sewers. The main sewerage works were commenced in 1862 and finished in 1875. In 1868 the entire volume of sewage

(about 8,000,000 gallons per day) flowed direct into the Bradford Beck, then a black and offensive stream. The Rivers Pollution Commission designated it "the most filthy stream they had met with, surpassing the "worst examples in Lancashire." Although the sewage was not worse in appearance than the water of the "Beck," into which it flowed, Mr. William Crompton Stansfield of Esholt Hall, near Apperley Bridge, considered himself aggrieved by the additional pollution which the sewage caused to the stream, and on the 28th of August 1868, he filed a Bill of Complaint in the Court of Chancery to restrain the corporation from causing or permitting to pass any sewage, filth, or other offensive matter, solid or liquid, into the Bradford Beck in such a manner that the same might pass therefrom into the river Aire to his injury, and prayed that damages might be awarded for all injuries suffered. On the 1st September 1868, the corporation was served with an interim injunction obtained ex parte from the Master of the Rolls, prohibiting them under a penalty of 10,000*l.* from opening or permitting to be opened any additional main or branch-sewer, or any house-drain or sewer into the outfall-sewer or into the Bradford Beck, or any sewer communicating therewith or emptying itself therein. An answer to the bill was filed, but negociations between the corporation and the Plaintiff ended in an arrangement whereby the injunction was dissolved upon terms, one of which was that the corporation should, on or before the 11th of January, take steps to defæcate the sewage passing through the public sewers. The corporation being convinced that any works merely dealing with the sewage of the town would fail to produce any appreciable improvement in the condition of the river Aire, they, in conjunction with other corporations and local boards in the watersheds of the Aire and Calder, introduced a Bill into Parliament during the Session of 1871 called the "Aire and Calder Conservancy Bill," which proposed to deal in a comprehensive manner with the sewage of the two watersheds. Violent opposition to this Bill was threatened, and it was consequently withdrawn. The same year the "Peat Engineering and Sewage Filtration Company," made an offer to the corporation to apply their system to the sewage of Bradford. Arrangements were made by which the corporation agreed to lease the sewage to this company for a term of 21 years, and to provide lands and buildings in which the operations were to be carried on; and the Company, on their part, agreed to purify the sewage, estimated at a daily volume of 8,000,000 gallons at their own expense, the residuum to become the property of the company. The company were also to have free use, for the first three years, of the buildings and plant to be constructed by the corporation; but after that period they were to pay the corporation a rent for the use thereof. These works were subsequently erected at a cost of 60,000*l.*, including land and incidental expenses. The company however failed to carry out the contract, and legal proceedings were commenced by the corporation against the company and their sureties to enforce the contract; but the company collapsed, and the corporation in 1874 took possession of the works.

The defæcation works are situate in a valley between Frizinghall and Massingham, and were specially constructed for carrying out the process of filtration by peat charcoal. This process failed, because the sediment, choked the filters; and as the filtering medium required to be constantly replaced, the cost was ruinous, and the process had consequently to be abandoned. The corporation then made such alterations to the works as to carry on a combined process of precipitation and filtration; and this method has for some time past been in operation for defæcating the sewage, which gravitates to the works, and flows into four subsidence tanks, from these tanks it passes along an

open conduit, across which iron screens are fixed to hold back any flocculent matters. Below the floor of the building, which is 700 feet long and 32 feet wide, there are 22 tanks, each tank 30 ft. × 32 ft. × 9ft. deep, and these, with the exception of the two middle ones, are used as precipitation tanks for the sludge. At the deepest point of these tanks connexions are made to a 9-inch cast-iron sewer pipe, through which the sediment is passed to "sludge-pits," one at each end of the building. The two middle tanks receive sewage from an "open conduit," and the coarser particles subside. After flowing through these tanks, lime, in the state of "milk of lime," is mixed with the sewage, which then flows along another open conduit into other precipitation tanks, of which there are 34. These tanks are each 22 feet wide by 24 feet long, and of an average depth of 5 feet, and are capable of holding about 18,000 gallons each, or together 612,000 gallons. The bottom of the tanks slope towards the filters, and after the sewage has been allowed to subside from 20 to 30 minutes, the supernatant liquid passes through a self-acting float-valve on to 34 filters; these are each 22 feet long by 12 feet wide by 2 feet deep, and are filled with coke. From these filters the clarified water passes into another open conduit, called the "effluent canal;" this runs along the entire length of the filter tanks, and is also partly filled with coke, and from this canal the treated sewage flows into the Bradford Beck. The sewage is allowed a period of from 20 to 30 minutes for subsidence in each tank, and as it only takes 15 minutes to fill a tank and 15 minutes for the clear liquid to run off, each tank, as constructed, is capable of defæcating 18,000 gallons per hour, and the 34 tanks 612,000 gallons per hour. The "sludge" from the tanks flows through a sewer to the sludge-pits, situate at either end of the main building; from these pits it is pumped into the tanks under the building, where it has an opportunity of parting with a portion of its moisture, and is thence removed to open sheds; and although it is there exposed to the air, it only loses a small quantity of its water, and the corporation propose to adopt artificial means to dry the sludge, of which about 22 tons are daily produced from the sewage of the town. The works have a railway siding to the Midland Railway on the one side, and are bounded by the Leeds Canal on the other, so that great facilities are afforded for the removal of the manure.

The quantity of lime required for precipitation of the sewage is one ton to every million gallons of sewage, but on Sundays, when the sewage contains no dye water, half a ton to every million gallons is found to be sufficient. The mixing and other machinery is at present driven by three portable steam engines of 10-horse power each, one in the centre of the building and one at each end.

The estimate for defæcating the sewage for the year 1876 is as follows:—

"Salary and Wages."

		£	s.	d.	£	s.	d.	£	s.	d.
Manager (G. Alsing)	-	-		-	300	0	0			
Foreman (James Lees)	per week	2	2	8	109	4	0			
Night do. (John Duxbury)	do.	1	10	0	78	0	0			
1 joiner	do.	1	12	0	83	4	0			
6 engine tenters (each)	do.	1	5	0	390	0	0			
18 labourers (day), with extra time, say 61 weeks	do.	1	4	0	1,317	12	0			
10 do. night	do.	do.	1	4	0	732	0	0		
								3,010	0	0

Brought forward -		£3,010	0 0

"Materials and Miscellaneous Expenses."

	£	s.	d.		
3,000 tons of lime - - -	1,875	0	0		
2,000 tons of breeze for filters - -	125	0	0		
1,040 tons of coke for fuel - -	637	0	0		
5 tons of coals - - - -	5	0	0		
Gas - - - - -	120	0	0		
150 gallons of engine oil - -	32	10	0		
224 lbs. cotton waste - - -	6	10	0		
220 lbs. candles - - - -	5	10	0		
Timber for keeping up plant, machinery, and buildings - - - -	50	0	0		
Repair of engines, machinery, &c. -	50	0	0		
Alterations and additions - -	100	0	0		
Office requisites - - - -	10	0	0		
Rates, taxes, and sundries - -	250	0	0		
				3,266	10 0
				£6,276	10 0

The corporation has not as yet been enabled to sell any of the sludge which consequently accumulates at the works.

In addition to the cost of defæcating the sewage, the annual cost of cleansing the 11,500 privies and 16,500 ashpits is 8,000*l.*, and the whole of the refuse removed therefrom becomes the property of the contractor and is disposed of by him.

Abstract.

Annual cost of treating sewage - - -	£6,276 10 0
Annual cost of cleansing privies - - -	8,000 0 0
Total - - - - -	£14,276 10 0

We collected samples of the solids extracted from the sewage before, and also of the sewage-sludge after treatment, and the following are the results of Dr. Voelcker's analyses.

Sludge from drying pits, no artificial heat being used.

On analysis the sludge as received, and calculated with 15 per cent. of moisture, furnished the following results:—

			Calculated with 15 per cent. of moisture.
Water - - - - - -		82·41	15·00
*Organic matter - - - -		7·54	36·44
Oxide of iron and alumina - - -		0·78	3·77
Tribasic phosphate of lime - - -		0·69	3·34
Carbonate of lime - - - -		5·66	27·36
Sulphate of lime - - - -		0·49	2·36
Alkaline salts and magnesia - - -		0·73	3·52
Containing—Potash - -	0·16		0·77
and chloride of sodium - -	0·11		0·52
Insoluble siliceous matter - - -		1·70	8·21
		100·00	100·00
* Containing nitrogen - - - -		0·14	0·67
Equal to ammonia - - - -		0·17	0·81

	£	s.	d.
In a ton of the wet sludge there are 17½ lbs. of phosphate of lime, worth at 1*d.* per lb.	0	1	5½
3½ lbs. of potash worth at 2*d.* per lb.	0	0	7
Nitrogen equal to 4 lbs. of ammonia at 8*d.*	0	2	8
Total estimated money value of 1 ton of wet sludge	£0	4	8½

	£	s.	d.
The dried sludge contains in 1 ton 75 lbs. of phosphate of lime, worth at 1*d.* per lb.	0	6	3
17½ lbs. of potash, worth at 2*d.* per lb.	0	1	10½
Nitrogen equal to 18 lbs. of ammonia at 8*d.* per lb.	0	12	0
Total estimated money value of 1 ton of dried sludge	£1	0	1½

For the selling value, see page lxiii.

Solids drained from Sewage before the Liming Process at Bradford.

A sample received in a partially dried condition had the following composition:—

			Calculated with 15 per cent. of moisture.
Water	51·41		15·00
* Organic matter	23·94		41·88
Oxide of iron and aluminia	2·63		4·61
Tribasic phosphate of lime	0·69		1·21
Carbonate of lime	4·07		7·11
Sulphate of lime	0·42		0·73
Alkaline salts and magnesia	1·28		2·24
Containing—Potash	0·47	0·82	
and chloride of sodium	0·03	0·05	
Insoluble siliceous matter	15·56		27·22
	100·00		100·00
* Containing nitrogen	0·44		0·77
Equal to ammonia	0·53		0·93

According to the preceding analytical results the sample with 51·41 per cent. of moisture contains in 1 ton—

	£	s.	d.
15½ lbs. of phosphate of lime, worth at 1*d.* per lb.	0	1	3½
10½ lbs. of potash „ 2*d.* per lb.	0	1	9
Nitrogen, equal to 12 lbs. of ammonia at 8*d.* per lb.	0	8	0
Making a total estimated value of 1 ton	£0	11	0½

The same material with 15 per cent. of moisture contains in a ton—

	£	s.	d.
27 lbs. of phosphate of lime, worth at 1*d.* per lb.	0	2	3
18 lbs. of potash „ 2*d.* per lb.	0	3	0
Nitrogen equal to 21 lbs. of ammonia at 8*d.* per lb.	0	14	0
Total estimated value of 1 ton	£0	19	3

For the probable value, see page lxiii.

COVENTRY.

Area (acres)	1,600
Population (about)	40,000
Rateable value	£101,438
Inhabited houses	10,400
Waterclosets	5,000
Cost of the main sewerage works	£33,000
Volume of sewage every 24 hours, about (gallons)	2,000,000
Privies	800
Cost of cleansing privies (yearly)	£1,050

Cost of farm for sewage irrigation, 27,000*l.* The farm has been let in consequence of the offer from the "General Manure and Sewage Company, Limited," freeing the corporation (for the time) from the responsibility of purifying the sewage.

The city of Coventry has been sewered; the works were commenced in 1853 and finished in 1855, at a cost of 33,000*l.* The whole of the sewage flows to one outfall at Whitley into the river Sherbourne, which is a small and rather sluggish stream. There are in the city 10,400 houses, and the excrements of the 40,000 persons who inhabit them are conveyed into the sewers by about 5,000 waterclosets, and consequently into the river into which the sewers discharge themselves, as there are only 800 privies. The sewers are ventilated by open grids in the covers of the 500 manholes, which are formed on the lines of sewers; they are also ventilated by being connected to fourteen factory chimney shafts, and further by the rain-water stacks from the eaves of houses. The whole of the rain-fall on the roofs and surface of the streets flows into the sewers, and from thence in heavy storms into the river by an overflow outlet specially provided for that purpose situate near Shut Mill Lane. Several springs were tapped while the sewerage works were being constructed, and a volume of about 500,000 gallons from this source enters the sewers daily. The waterworks belong to a private company, and 720,000 gallons of potable water are daily delivered for the use of consumers. There are also 21 public wells and a great many private wells from which a considerable number of the inhabitants obtain water for domestic purposes.

In 1860, complaints having been made by riparian owners of the pollution caused to the river Sherburne, the corporation directed subsidence tanks to be constructed near the river, and the outfall to be diverted so that the sewage might be discharged into the tanks, and afterwards filtered through a medium of gravel 3 feet in thickness before it entered the river. The tanks and so-called filters were a failure as regards purifying the sewage; they only partially extracted the suspended matters, and left the putrescible organic matters in solution, and although this somewhat mitigated the nuisance, it did not produce any substantial diminution of the polluting quality of the liquid.

Further complaints having been made of the condition of the river, the corporation, as advised in 1869, purchased 262 acres of land at Whitley at a cost of 27,000*l.*, and instructed Mr. T. Hawkesley, M. Inst., C.E., to prepare a scheme for laying it out as an irrigation farm; and he subsequently submitted plans and an estimate of the proposed works. The sewage would, owing to the configuration of the land, have to be pumped on to the farm, and this circumstance, in addition to the great cost of the proposed works, caused the corporation to postpone carrying out the scheme. In August 1870, the A. B. C. or "Native "Guano Company," made an offer to the corporation to treat the sewage of the city by their process, but the terms proposed by the corporation

were not accepted by the company. On the 25th September 1871, Mr. H. M. Jackson, a riparian owner, filed a bill of complaint in Chancery and applied for an interlocutory injunction to restrain the corporation from passing sewage into the river, but the court declined to grant the injunction and the suit was abandoned.

In 1872, the "Peat Engineering and Sewage Filtration Company," made an offer to the corporation to deal with the sewage by their process, but this offer the corporation did not entertain.

On the 25th of October in the same year, the corporation entered into a contract with the "General Sewage and Manure Company, Limited," whereby a messuage and 28 acres of land at the outfall works were leased by the corporation to the company for 14 years at a rent of 75*l.* per annum, together with the sewage of the city. The company covenanted to erect the necessary buildings; to furnish the requisite machinery and plant; to effectually deodorize and purify the whole of the sewage of the city, and to pass the clarified water therefrom into the river Sherburne, and they further covenanted that if default is made, after six weeks' notice, in carrying out the conditions of the lease, the corporation shall have power of re-entry and to put an end to the lease; whereupon all buildings and works shall become the property of the corporation without payment or compensation to the company; and the corporation are also to have the option of buying the steam engines, machinery, and other effects on the works at a valuation.

The company were to commence to treat the sewage on the 29th of September 1873, but it was not until May 1874 that the works were sufficiently completed to enable them to do so.

The "General Sewage and Manure Company Limited" was formed in 1872, with a primary object of working on a practical scale the process for the purification of town sewage patented by Dr. Anderson, but the company have also acquired other patents for improving this process. The works erected by the company at Coventry, at a cost, including machinery and plant, of 12,000*l.*, are situated on the right bank of the River Sherburne about two miles from the city. The sewage, estimated at 2,000,000 gallons every 24 hours, is weak owing to the large volume of subsoil water which mingles with it on its passage through the sewers. On the sewage reaching the works it passes through "extractors" which remove the coarser parts of the suspended matters, and it then flows into circular mixing tanks, constructed beneath the floor of the first block of buildings, to these tanks are affixed "agitators" driven by steam power for thoroughly mixing the compound which is here added to the sewage in such quantities as from time to time is required. This mixture consists of a saturated solution of crude sulphate of alumina, which has been heated to the boiling point, and this is prepared at the works from ordinary clay, or from shale of the coal measures, treated with concentrated sulphuric acid (an aluminous shale is at present used). From the mixing pits the sewage flows into another series of tanks under the floor of the second block of buildings, and in these tanks "lime" in the condition of so-called "milk" is added to the sewage which is here also continuously agitated by machinery."

From the "liming-tanks" the defæcated sewage flows into uncovered subsidence-tanks; these are four in number, and each tank is cleaned out every fourth day. The supernatant liquid flows from these tanks in a tolerably clear condition into a conduit which discharges it on to an area of about 4½ acres of loamy soil adjoining the works. This land has been roughly laid out as a land-filter and drained about five feet deep with an outlet at the extreme end of the land into the river Sher-

borne. On the date of our visit to the works the effluent water flowing from this outlet was clear and inodorous. The sludge precipitated into the tanks amounts to about 30 tons daily, and this, after being passed through a further straining process, is placed in heaps at the works to lose a still further portion of its moisture. We observed a large accumulation of this deposit. In order to convert the semi-dried sludge into a manure it is further dried by artificial heat by the use of Messrs. Milward's sewage mud-drying machines.

The company treat by their process the sewage flowing to the works between the hours of 5.30 a.m. and 11 p.m., but the sewage of the night (*i.e.*, from 11 p.m. to 5.30 a.m.) flows through the tanks, and on to the filtering area without chemical treatment. The company say that the sewage during that period is chiefly subsoil water, and it only needs to be passed through the tanks mixed with the chemically treated sewage which they contain, and then flow on to the filter beds."

By the courtesy of Messrs. J. C. Melliss and E. F. Coddington, the engineer and the manager of the works, we are enabled to give the working expenses of the company.

Working Expenses, Weekly.

	£	*s.*	*d.*
22 tons of coal, at 10*s.* 6*d.* per ton	11	11	0
27 cwt. of sulphuric acid, at 76*s.* 6*d.* per ton	5	3	3
9 tons of sulphate of alumina, 27*s.* 6*d.* per ton	12	7	6
4½ tons of lime, at 16*s.* 2*d.* per ton	3	12	9
Labour (12 men)	16	0	0
Contingencies	1	5	6
	50	0	0

This amounts yearly to a sum of 2,600*l.*; to this must be added the salary of the manager, 250*l.*, and also a sum for repairs and depreciation of works and plant, also the interest on capital expended, say 600*l.*, per annum.

Abstract.

Annual cost of treating the sewage	£2,600	0	0
Manager's salary	250	0	0
Interest on capital expended	600	0	0
Total	£3,450	0	0

There is difficulty in getting rid of the sludge, as also of selling the manure when manufactured, but in January of this year (1876) owing to the exertions of the bailiff of the company's farm, the farmers in the neighbourhood have purchased and given orders for 350 tons; of the sludge to be taken direct from subsidence-tanks at 3*s.* per ton, this sludge, costing 4*s.* 10*d.* a ton to produce, when not at once removed, is placed in heaps about the works exposed to the atmosphere, to get rid of some of its water, afterwards if dried by artificial heat it costs in addition 1*l.* 8*s.* 9*d.* per ton, but if there was a demand for the manure, necessitating its being passed through a filter, and also artificial heat being applied to dry it, the cost would be 2*l.* 10*s.* per ton.

The manure thus produced in a dry state is then ground to powder, for sale to farmers.

We collected a sample of the sludge from a heap on the works, and have caused it to be analyzed by Dr. A. Voelcker, F.R.S., and the following are the results.

ANALYSIS of MANURE prepared by the GENERAL SEWAGE MANURE COMPANY at COVENTRY.

A sample of the Coventry sewage manure was found of the following composition :—

Moisture		47·36
*Organic matter		15·95
Oxide of iron and alumina		5·17
Tribasic phosphate of lime		1·81
Carbonate of lime		7·32
Sulphate of lime		1·19
Alkaline salts and magnesia		2·38
Containing potash	0·20	
and chloride of sodium	0·02	
Insoluable siliceous matter		18·82
		100·00

*Containing—Nitrogen	0·69
Equal to ammonia	0·84

According to the preceding analytical results 1 ton of the Coventry sewage manure contains :—

	s.	d.
40½lbs. of phosphate of lime, worth at 1*d.* per lb.	3	4½
4½lbs. of potash „ 2*d.* „	0	9
Nitrogen equal to 19lbs. of ammonia at 8*d.* „	12	8
Total estimated money value per ton	16	9½

For the value to the farmer, see page lxiii.

These works have, from the first, been carried on at a loss of not less than 1,500*l.* per annum for each million gallons of sewage per day treated; and, apparently, this rate of loss must continue, so long as this mode of treatment is continued.

The Corporation cleanse about 800 privies annually, removing 6,600 loads of refuse, at a cost of 1,050*l.*

LEEDS.

Area	(acres)	22,000
Population (about)		285,000
Rateable value		£945,141
Waterclosets (about)		8,000
Main sewerage works cost about		£240,000
Estimated daily volume of sewage (about)	(Gallons)	12,000,000
Estimated quantity of "sludge" produced daily	(tons)	40

Or about 15,000 tons annually.

Experimental and permanent works for A. B. C. process at the outfall Knostrop, cost	£47,000
Borwick's machines for drying the mud cost	£4,000
Total cost	£51,000
Annual cost of treating sewage by A. B. C. process	£15,000
Number of privies (about)	15,598
Annual cost of cleansing privies and middens	£27,000
Amount received for about 80,000 loads of refuse removed	£9,000

The borough of Leeds has been sewered, and the main outfalls were, until 1852, direct into the river Aire. The sewage was then inter-

cepted and conveyed to one outfall at "Knostrop." Waterclosets are connected with the sewers, and the privy cess-pits and ash-middens are also drained into them; the sewage is however weak as compared with the sewage of London. The Rivers Pollution Commissioners collected samples of the Leeds sewage, flowing from the works at Knostrop, and submitted them to analyses, and in speaking of the result said. "The Leeds sewage contained a large portion of suspended matters; but it was very deficient in soluble fertilizing ingredients, containing only about one third of the proportion present, in average London sewage. This latter circumstance is due partly to the discharge of much slightly polluting water from factories into the sewers, and partly to the circumstance that 'springs were tapped during the execution of the sewerage works.' It is, however, probable that the sewage was exceptionally weak, at the time our sample was collected (1.30 p.m.) since Glasgow, with a daily water supply of more than 50 gallons her head, furnishes sewage twice as rich in fertilizing ingredients as that of Leeds." The nuisance caused to the river by the sewage is aggravated by the entire volume being discharged through one outfall, at Knostrop, and Sir Charles Hugh Lowther, Bart., and Mr. J. T. Leather, riparian owners, whose lands are situated a short distance below the outfall works, filed on the 5th November 1869, a Bill of Complaint in Chancery, and obtained a perpetual injunction to restrain the corporation from polluting the river Aire by the sewage, at Knostrop; the Court on application of the defendants granted two years from the date of the decree, in which period the corporation were to devise and carry out a scheme for abating the nuisance; but the time not proving sufficient to enable them thoroughly to investigate the various remedial processes proposed for consideration, they made further applications to the Court, and on three occasions the time was extended, the last extension was to 1st March 1874. In 1870 the A. B. C. or "Native Guano Company" made an offer to the corporation to treat by their process (for a limited period) the sewage discharged from the works at Knostrop, and also to pay the costs of the materials and labour required to carry on the process, provided that the corporation would bear the cost of erecting experimental works and supplying the necessary machinery for the purpose; this the corporation agreed to do, and the works, fitted with the necessary plant, were erected at a cost of 10,000*l*. The company carried on the process for some time; but the corporation had no control over the quantity of the chemicals used. On 17th August 1870 an agreement was entered into between the corporation and the A. B. C. Company, by which the corporation undertook to erect permanent works according to plans furnished by the company, for treating the entire volume of sewage (estimated at 12,000,000 gallons daily), and the company, on their part, undertook to be at the expense of successfully purifying and deodorising that volume of sewage, and to manufacture the "sludge" into a manure, and out of any profits from the sale of such manure to pay to the corporation 15 per cent. of the profits. The works were commenced in 1872 and finished in 1875, at a cost of 47,000*l*. Before the completion of the permanent works the company applied to the corporation to release them from the penalties of the contract, and they alleged as a reason for this request that they could not sell the manure which they had already manufactured at the experimental works, and offered, as a consideration for being released, to allow the corporation, without paying royalty, to use all the patents obtained by the company for "treating sewage water and matters." Eventually, the corporation consented to cancel the agreement, and on this being done the A. B. C. Company vacated the works. Some time after Major-General Scott, C.B., and afterwards Mr. Rupert Goodall,

and finally Mr. Sylvester Fulda were permitted to carry on experiments with their several processes at the sewage works; the result was that Goodall's process (*i.e.*, treating the sewage with lime, ground coal ashes, nitrate of iron, and carbon, a waste product from the manufacture of prussiate of potash) promised the best effect. The cost of this process for treating the entire volume of the night and day sewage flowing from the works at Knostrop was estimated at 19*s.* per hour, and arrangements were subsequently (in August 1874) made by the corporation with Mr. Goodall to carry on the work for a period of six months; but at the end of that time it was found that the sewage could be clarified on a larger scale at a cheaper rate than it had been done at the smaller works, and it was considered advisable to try the process of the A. B. C. Company at the large works, which were originally built for the A. B. C. process, and from January 1875 to January 15th, 1876, the A. B. C. method was carried out at a cost during this year (for lime, carbon, alum, clay, and carbolic-sulphide, inclusive of labour, fuel, oil, tallow, &c.) of 15,000*l.* This amount is exclusive of the cost of drying the deposit and converting it into a manure, which has not as yet been done.

The corporation have recently (January 1876) arranged with Mr. John Hanson, a manufacturing chemist of Savill Town, near Dewsbury, to treat the sewage by a process for which he has obtained a patent, and he proposes to use, in treating 12,000,000 gallons daily,—

	£	*s.*	*d.*
Six tons of lime at 14*s.* 6*d.* per ton - - - - -	4	7	0
Seven tons of black-ash at 8*s.* per ton - - - -	2	16	0
Seven tons of new material (as to which no information was given) at 7*s.* per ton - - - - - -	2	9	0
	£9	12	0

Or at a rate of 16*s.* per million gallons per day for chemicals alone. To this must be added the cost of labour, coal, and other materials, also the expense of cleaning out the sludge-tanks, and of artificially drying the "sludge" and converting it into a manure. It is estimated that the quantity of suspended and precipitable matters in the Leeds sewage amounts to 40 tons daily, or about 15,000 tons per annum, and not any of this has been sold, which consequently accumulates at the works.

For the purpose of artificially drying the mud and manufacturing a manure therefrom the corporation are erecting two of Borthwick's drying cylinders; these will cost about 4,000*l.*

The Rivers Pollution Commission carefully investigated the A. B. C. process, and in their second Report, 1870, submitted the conclusions regarding it to which their inquiries, observations, and analyses had led them. They say, "As therefore the inevitable conclusion is unfavourable to the A. B. C. process, in respect of its alleged power to hinder the pollution of rivers by town sewage, so also is it altogether unfavourable to the value of the manure which it manufactures. The one statement is, indeed, in some sense the complement of the other, for just in proportion to the largeness of the amount of fertilising matter which escapes must be the comparative worthlessness of the small remainder which is retained."

We collected a sample of the sludge from the A. B. C. process and caused it to be analysed by Dr. A. Voelcker, F.R.S., and the following are the results of the analysis:—

DEPOSIT from the SEWAGE of LEEDS treated by the A. B. C. process.

This deposit in the state in which it was received, and calculated for 15 per cent. of moisture, had the following composition :—

		Calculated with 15 per cent. of moisture.
Moisture	57·20	15·00
*Organic matter	9·45	18·77
Oxide of iron and alumina	8·10	16·09
Tribasic phosphate of lime	0·76	1·51
Carbonate of lime	5·60	11·12
Sulphate of lime	0·45	0·89
Alkaline salts and magnesia	1·40	2·78
Containing—Potash	0·39	0·77
and chloride of sodium	0·02	0·04
Insoluble siliceous matter	17·04	33·84
	100·00	100·00
* Containing nitrogen	0·31	0·61
Equal to ammonia	0·37	0·74

	£	*s.*	*d.*
The partially dried deposit containing 57·20 per cent. of moisture contains in 1 ton 17 lbs. of phosphate of lime, worth at 1*d.* per lb.	0	1	5
8¾ lbs. of potash, worth at 2*d.* per lb.	0	1	5½
Nitrogen equal to 8¼ lbs. of ammonia at 8*d.* per lb.	0	5	6
Total estimated money value per ton	£0	8	4½

In a ton of the deposit, with 15 per cent. of moisture, we have—	£	*s.*	*d.*
34 lbs. of phosphate of lime, worth at 1*d.* per lb.	0	2	10
17¼ lbs. of potash, worth at 2*d.* per lb.	0	2	10½
Nitrogen equal to 16½ lbs. of ammonia at 8*d.* per lb.	0	11	0
Total estimated money value of 1 ton	£0	16	8½

For the true value, see page lxiii.

The cost of treating the sewage in this case is not less than 1,500*l.* per annum for each million gallons per day, and there is no probability of reduction if the present mode is continued. The Committee of Works persist in expecting 1*l.* per ton for the manipulated sludge, which they do not obtain; recently (July 1876) they assert that it is selling at 10*s.* per ton.

In addition to the expense of clarifying the sewage by chemical treatment, there is the cost to the corporation of cleansing the 15,598 privies and middens, removing the refuse (about 80,000 loads) at a cost of 27,000*l.* The expense of cleansing and removing is partly recouped by sale of the refuse, which realizes 9,000*l.*, or at a rate of 2*s.* 2½*d.* a load, leaving a deficit of 18,000*l.* The refuse is bought by farmers to be used for manure.

The sewers are ventilated, and, in 1873, 15,000 gullies were converted into ventilators. In the construction of all new sewers ventilating-shafts are built, the gullies are also ventilated, and arrangements are also made for flushing the sewers.

HALIFAX.

Area	(acres) 3,768
Population, about	68,000
Rateable value	£262,581
Inhabited houses	11,218
Waterclosets	2,600
Sewerage works cost	£77,000
Outfall works and tanks cost	£15,954
Estimated volume of sewage every 24 hours (gallons)	2,500,000
Yearly cost of cleaning tanks and removing refuse	£213
Privies on the Goux system	3,159
Yearly cost to corporation of cleansing these receptacles	£1,896
Privies with middens on old system	1,500
Yearly cost to corporation of cleansing these "middens"	£1,100

The borough of Halifax has been sewered; the main sewers are built of stone and brickwork, and the branch sewers are formed of stoneware pipes, the main outfall being into the Hebble at Salter Hebble. The sewers are ventilated by means of side chambers built to each manhole; these are carried up to the surface of the streets and are covered by open grids. The Hebble, a small stream, in its passage through the town is considerably discoloured by refuse from mills and dye works; and, in 1869, it was greatly polluted by sewage. In the month of May of that year, Messrs. J. Holdsworth and Company, whose mill is on the stream about a quarter of a mile from the outfall sewer, filed a bill of complaint in the Court of Chancery, and in July of the same year an injunction was granted to restrain the corporation, from and after the 1st of June, 1870, from causing or permitting the sewage of the borough to flow into the Hebble Brook until the same had been sufficiently purified and deodorised. In February 1870, the late Mr. John Lawson, C. E. (Lawson and Mansergh) at the instance of the corporation, visited Halifax, and after an examination of the district submitted a report on the best mode of disposing of the sewage thereof; he recommended that "an irrigation scheme on a comprehensive scale should be carried "out, and he considered that the 475 acres of land proposed to be pur-"chased by the corporation would probably be sufficient for the "thorough utilization and purification of the sewage of Halifax": he also stated that "tanks or screeners would be required to take out the "suspended matters, and the sewerage could be delivered on to the "greater part of the land by gravitation." The recommendation of Mr. Lawson was not adopted by the corporation, who in the autumn of 1869 called in Mr. J. Bateman, C.E. to advise them, and he recommended that subsidence tanks should be constructed, and that an intercepting sewer of cast-iron pipes, from 18 inches to 30 inches in diameter, should be laid to convey the sewage of Halifax and discharge it into the tanks and thence into the stream at a point below the plaintiff's works; the intercepting sewer and tanks were completed before the 1st of June 1870, and this satisfied the Plaintiffs in the suit. The cost of these works was 15,954*l*. The volume of sewage flowing through the outlet is estimated at 2,500,000 gallons every 24 hours, and in this volume is included about 500,000 gallons of subsoil water. The sewage is not treated by any chemical agent, but flows into the subsidence tanks where the coarser matters and detritus are arrested, but the raw sewage, loaded with the foul matters in solution, passes from the tanks into the Hebble Brook.

In 1871 the Goux Manure and Sanitary Company, Limited, applied to the corporation to be allowed to introduce their dry system into the borough; and offered free of cost to cleanse all the privies which were or would be constructed on the plan they laid down, (*i.e.*) "The ashpits and excrement pits under the privy seats were to be thoroughly cleansed, and filled in with dry rubbish to the level of the floor, and the privy seat was to be made removable so that it could be lifted up to place in, or take away, the 'receiver' or 'tub'; these tubs were to be 30 inches in diameter and 16 inches deep, and in them a certain quantity of absorbent, either of vegetable or animal fibrous matter, was to be placed, a core was to be inserted around which was to be filled in a further quantity of absorbent matters, and the core was then to be removed. The tubs so prepared were to be placed under the privy seat to receive the excreta, and were to be removed and replaced every eight days; the tubs were, when full, to be taken to the depôt, and their contents emptied and mixed together."

The corporation accepted the offer of the company, and the company erected temporary works and plant on land belonging to the corporation at Stone Dam in the borough, but as this land was subsequently required for other purposes, the corporation in March 1873 let to the company land at Salter Hebble, close to the sewage outfall works, at which place the company erected sheds, stables, and offices, for carrying on the process.

About this time the company represented to the corporation that they could not sell the manure manufactured by their process, and that they were losing by the work; and the corporation agreed to pay to the company 7*s.* per annum for every Goux closet cleansed, and if the contract remained in force after the 1st of January 1875, this amount was to be increased to 12*s.* per closet, subject to three months' notice on the part of the corporation, and 12 months' notice on the part of the company. The company gave notice to the corporation in January 1875 to terminate the contract in January 1876, and the corporation are now considering whether they will or not carry on the system.

The company under their contract with the corporation removed about 500 tubs daily from the closets to the works; these tubs were about two thirds full of excreta, and after being emptied of their contents ought to have been thoroughly washed before being prepared for re-use, and although the company professed to have this necessary work done, we saw on the day of our visit to the works, January 16th, 1876, the tubs being lined with the absorbent, and prepared to be used again, without having first been properly cleansed.

The company used at Halifax the refuse shoddy as an absorbent lining for the tubs for which they paid 9*s.* per ton; the contents of the tubs were, when taken to the works, mixed and turned over in a pit, and afterwards thrown into a heap in the store shed. We saw at least 2,000 tons of this feeble manure stored in that shed, the Company not being able to sell it at the price they asked for it, viz., 15*s.* per ton.

For carrying out their system at Halifax the company expended in erecting sheds, buildings, and cottages, and also in making a road to the works, the sum of 2,000*l.*, and a further sum of 500*l.* in providing the necessary horses, waggons, carts, and barrows.

The receipts and expenditure of the company at Halifax for 1875 were as follows :—

Receipts.	£	s.	d.	Expenses.	£	s.	d.
Received of the corporation for cleansing 3,159 closets	1,895	0	0	1 manager 1 inspector 1 foreman 10 collectors 8 drivers 4 emptiers and packers 1 boy Keep of 7 horses Hire of 8 ditto	3,276	0	0
Sale of manure	700	0	0	400 tons of shoddy	180	0	0
Balance (loss)	911	0	0	Gypsum and charcoal	50	0	0
	£3,506	0	0		£3,506	0	0

The Rivers Pollution Commissioners, in referring to this process said :—

" It must be remembered, as regards this, and similar expedients, not only that it is but a part of the excrementitious matters which is dealt with, but that even as regards that portion of the excrement which they do remove, they so entirely depend upon efficient cleanly superintendence and direction, that wherever they have merely had the average man to work them, they have failed. Moreover, this very frequent collection of filth by hand from houses, and its removal sometimes through the cottages themselves, almost necessarily under the eye and nose of the household, whatever may be the importance of the economic object aimed at, is universally condemned by our domestic habits as nasty and offensive."

The yearly cost to the corporation of cleansing the old middens, of which there are 1,500, is 1,100*l.* ; the refuse becomes the property of the contractor.

We collected a sample of the manure manufactured by the Goux Company from the store-shed on the works at Halifax, and have caused it to be analysed by Dr. A. Voelcker, F.R.S., and the following are the results :—

Manure manufactured by the Goux Company at Halifax.

A sample of this manure on analysis gave the following result :—

Moisture		51·65
*Organic matter		22·70
Oxide of iron and alumina		3·96
Tribasic phosphate of lime		0·96
Sulphate of lime		0·81
Alkaline salts and magnesia		2·37
Containing—potash	0·30	
and cholride of sodium	0·38	
Insoluble siliceous matter		17·55
		100·00
*Containing—Nitrogen		0·67
Equal to ammonia		0·82

A ton of this manure contains—			s.	d.
21½lbs. of phosphate of lime, worth at 1*d.* per lb.	-		1	9⅓
6¾ lb. of potash „ 2*d.* „	-		1	1½
Nitrogen equal to 18⅓lbs. of ammonia, at 8*d.* per lb.	-		12	5½
Total estimated money value per ton	-	-	15	4½

For the true value, see page lxiii.

ROCHDALE.

Area		4,136
Population (about)		67,000
Rateable value		£222,000
Inhabited houses		14,288
Waterclosets		350
Cost of sewage, manure, works, and plant		£10,000
Volume of sewage every 24 hours	(gallons)	1,250,000
Privies, "middens"		2,844
Privies, "pail system"		5,462
Yearly cost of cleansing privies on pail system		£3,405
Excreta removed yearly	(tons)	4,224
Manufactured into manure	(tons)	3,741
Manure sold	(tons)	2,000
Yearly cost of cleansing "middens"		£1,919
Refuse removed	(tons)	13,736
Refuse, 5,736 tons, sold for		£549

Rochdale has adopted the "pail" system for the disposal of the excrements of its 67,000 inhabitants living in 14,388 houses distributed over an area of 4,136 acres, as there were in use on the 28th of January 1876, 5,462 privies on the "pail" system, 2,844 "middens," and only 350 waterclosets, and we were informed that the "middens" are being converted into privies on the "pail" system, at the rate of 20 per week.

The borough has been sewered and these works have been greatly increased since 1853.

In 1853 the corporation obtained an Improvement Act, and the 96th section of that Act provides that it shall not be lawful for the corporation to cause any new sewer to open or drain into the River Roch at any point above the Town Mill Weir, or the stream called the Lord Burn; but, as the town rapidly extended, new sewers were constructed, and this greatly augmented the volume of sewage flowing into the Roch and seriously polluted it. On the 6th of October 1869 a Bill of Complaint was filed in the Court of Chancery, by Mrs. Sophia Holt (widow), and Messrs. Oliver Holt and William Holt, praying that the corporation be restrained from permitting the new sewers then being laid down in Yorkshire Street or any other new sewer from emptying into the Roch above the Town Mill Weir or into the Lord Burn. On the hearing of the cause, 3rd of January 1870, Vice-Chancellor James granted an injunction as prayed. In order to satisfy the Court, and also with a view of intercepting the sewage and preventing it from polluting the Roch, the corporation, in session 1872, introduced a Bill in Parliament and sought certain powers, one of which was to acquire 1,000 acres of land and on this area to utilize the sewage by irrigation. The land is situate in the township of Unsworth about 5 miles from Rochdale, and is the property of the Right Honourable the Earl of Derby. There was great opposition to the Bill and the clauses relating to the land for irrigation were struck out. The corporation then caused

plans to be prepared of an intercepting sewer to divert the sewage from the Roch, and this work is now being carried out a cost of 20,000*l*. The intercepting sewer commences at Ashbrook Valley on the eastern boundary of the borough, and from that point to Heybrook Valley, it is 4 feet in diameter and laid at a gradient of 1 in 250; from Heybrook Valley to George Street it is increased to 5 feet in diameter; from thence to Duke Street it is further increased to 6 feet in diameter; from thence to the Spodden Valley, it is 6 feet in diameter, but laid at a gradient of 1 in 1,000; and from the Spodden Valley to the outfall into the Roch, below Oaken Rod Weir, it is 9 feet in diameter; laid at a gradient of 1 in 1,000.

When these works are completed there will still be 12 overflow-outlets into the Roch, above the Town Mill Weir, to relieve the main sewers of flood water during heavy storms of rain.

The sewers are ventilated by open grids in the covers of the lamp-holes and manholes; these are placed on the lines of sewers and are not more than 150 feet apart. Owing to the configuration of the town the sewers have steep gradients, and it was found that a considerable volume of sewer gas ascended to the highest points of the system; to remedy this, self-acting valves (as recommended in the published suggestions of the Local Government Board, pages 7, 8, 9,) are placed in each manhole, and this has had a beneficial effect; it has prevented the sewer-gas accumulating at the higher points and has facilitated its escape through the gratings in the surface of the streets.

The volume of sewage entering the Roch, Spodden, Hey-Brook, and Sudden Brook, by the numerous outlets, is about 1,250,000 gallons every 24 hours.

In 1869, the corporation of Rochdale decided that they would not continue the contract for cleansing middens and removal of the contents; and, after some consideration as to the best form of privy and ash place, they adopted the "pail," or that now known as the "Rochdale system."

The corporation have erected buildings as a depôt on a site within the borough, and purchased the necessary plant, horses, and rolling-stock for collecting the excreta and refuse at short intervals. The cost of the works, plant, and stock, up to the 28th of January 1876, has been about 10,000*l*.

The mode of collection is as follows:—"The town is divided into six districts, and each pail-privy is numbered consecutively in a district register, so that in case of any contagious or infectious disease arising in the town, the numbers of the pail-privies in connexion with the houses in which the disease exists can be communicated to the local authority, when arrangements can be made for the daily disinfection of such pail-privies, and for the isolation of such excreta."

"As a rule all pail-privies are empted once a week, to ensure which the driver of the collecting van, on his return to the works, gives in a list showing the number of each pail-privy from which he has collected: this is posted in a book, in such a form that it can be seen at a glance whether any have been neglected, and on every Monday morning a list of those overlooked (if any) is made, and a supplemental van is then sent out to make good the week's collection; the entire onus of removal rests upon the corporation."

"The pail-privies are supplied at each collection with a fresh pail, which has been well washed, and in which has been placed a liquid deodorizer and disinfectant."

"The collections, according to the regulations, should be made between the hours of 7 a.m. and 5·30 p.m."

To prevent any nuisance arising from the collecting van when passing through the streets on its return to the works, air-tight lids are placed

upon each pail; the doors of the van also close against india-rubber beads fixed in the rebates, so as to be air-tight.

The ash and refuse-tubs are also emptied systematically, attention being secured to them by the weekly visits which are paid to the privies.

In emptying the tubs the ashes are not thrown on the ground, but are emptied directly into a cart, and before placing the tub again in position the floor of the ash-place is swept.

The process of manufacturing the manure is as follows:—the wet-house refuse is tipped from the carts on to drying floors, and when thoroughly dry is, with the other refuse, passed through a riddling machine worked by steam power, which holds back the paper, vegetable, and other refuse, and separates the cinders in two sizes from the ash; the ash is then removed to any part of the sheds where required, and the cinders are removed and used on the works for generating steam, heating the drying floors, and also for firing the boilers at the public baths; and some of the cinders remain for sale. All refuse, such as scrap-iron, obtained by this riddling is disposed of; the vegetable refuse is burnt, and the ash used in the manure.

The excreta, upon its arrival at the works, is emptied into a trench formed by banks of ash, previously brought into the shed from the riddling machine; when this trench is full a quantity of ash is thrown upon the excreta, and the contents are treated with sulphuric-acid, in the proportion of 24 lbs. of acid to each ton of excreta.

The proportion in weight of the excreta and ashes thus treated are about equal. Trench after trench are formed and filled until the whole floor of the shed is covered. When seven days have elapsed since the formation of the first trench and the ash there used has become sufficiently dry to be again used as an absorbent, new trenches are made in the banks of ash deposited to form the sides of the first trenches, and these are filled with excreta and the ash covered over them and again treated with sulphuric acid, as in the first instance. In this latter case, as ash is only required to cover the excreta, and not to form the banks of the trenches, only 5 cwts. of ash are used to 20 cwts. of excreta. When this second course has covered the area of the shed, the process is repeated in another shed, leaving the first shed at rest for fourteen days, after which it is again treated for a third and also for a fourth time with the like quantity of excreta and ash used in the second course. The total quantities thus treated having become 35 cwts. of ash to 80 cwts. of excreta, the mass is undisturbed for fourteen days, after which it is turned over and remains another seven days, when it is again turned over and for a second time allowed to remain undisturbed for seven days. By this time the mass has become a powdery manure, and is in a condition to be bagged for sale.

In 1875, the cost of collection of the pail-refuse and manufacture of the manure, together with the estimated value of the manure manufactured, was as follows:—

	£		£
Cost of collection - -	3,405	Value of manure manufactured estimated at 1*l.* per ton -	4,420
Cost of manufacture - -	3,651	Loss - - - -	2,636
	£7,056		£7,056

Note.—The Rochdale manure is not readily taken away from the yard at the estimated price of 1*l.* per ton, but gradually accumulates. This is the experience in all cases within our knowledge of this and similar modes of dealing with excreta.

We saw at the works about 7,000 tons of this manure. There is not a ready sale for it. Only 2,000 tons were sold in 1875; the corporation in consequence caused the manufacture to cease. Since April of that year, 1875, the excrements have merely been mixed with house-refuse and ashes, but there is great difficulty in getting rid of the mixture although the corporation undertake to deliver it to the purchaser at 2*s.* 6*d.* per ton, and this appears to be the true value to farmers.

The cost of cleansing the middens and removing the contents is 1,919*l.* per annum, and of the 13,736 tons of refuse removed 8,000 tons are deposited in "tips" within the borough, and for the remaining 5,736 tons the corporation receive the sum of 549*l.* 2*s.* 11*d.*

With reference to the 8,000 tons of "midden" refuse thrown away on "tips," we quote the remarks of the Rivers Pollution Commissioners on the "Collyhurst Tip" at Manchester (see Report Mersey and Ribble Basins, p. 24) "The contents of these ashpits are divided by the scavengers into so-called *dry* and *wet*; and it is a matter of serious importance that it is the latter or obviously filthy part alone which is carried to the manure depôt, the dry rubbish being carried to any place that may be in course of levelling in the outskirts of the town. Of course such a division is most imperfectly made under such circumstances; and it follows that the land is thus filled up with the most objectionable stuff; and as building extends, the surface is gradually covered with houses which, on such foundation, cannot fail to be unwholesome dwelling places. There is now a "tip" in a ravine at Collyhurst, on the north side of Manchester, where land is thus being raised *fifteen* to *twenty* feet over many acres, by the gradual accumulation of filthy rubbish. A sample of water from a pool at the foot of this tip on the outer side of the Queen's Road, which here crosses the ravine, taken a few minutes after rain, so that it represented the drainage water of this bank, and thus fairly indicated the nature of the stuff it had trickled through, and another sample taken at a later date yielded the following results on analysis.

"Composition of Drainage Water from Collyhurst "Tip."

"Results of Analysis expressed in Parts per 100,000.

Dates of collection of samples.	Total solid Matters in Solution.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total combined Nitrogen.	Chlorine.	Matters in Suspension.	Organic Matters in Suspension.
June 12, 186 - -	1643·5	32·278	3·631	29·525	0	27·946	831·5	16·88	13·48
July 21, 1869 - -	2310·4	22·591	5·257	15·440	0	17·972	440·0	54·36	26·52

"It will be seen from the above numbers that these liquids contained a very large proportion of highly offensive organic matter. They were, in fact, much richer in putrescible matters than any watercloset sewage we have met with. The whole of the made land, indeed, here smells most offensively and can never be built upon without great risk to the health of those who shall occupy the houses. And this is no exceptional example connected with the midden system. What to do with the fouled ashes, which it accumulates—filthy stuff, too poor for use as manure—is one of the great difficulties of the local authorities almost everywhere in Lancashire."

Results of Analysis of Pail and Ash Manure.

We collected at the depôt a sample of the manure manufactured from the refuse of the "pails," and have caused it to be analysed by Dr. A. Voelcker, F.R.S., and the following are the results :—

This manure is prepared at the Sanitary Manure Works belonging to the corporation of Rochdale, from the contents of pails in which human excreta are collected; these are dried up with finely-sifted coal ashes, and delivered to farmers in a more or less dried condition.

A sample of the Rochdale manure as received contained the following ingredients:—

Moisture		15·13
*Organic matter (including carbonaceous matter from finely sifted cinders)		30·62
Oxide of iron and alumina		17·27
Tribasic phosphate of lime		0·76
Sulphate of lime		4·82
Alkaline salts and magnesia		2·29
Containing potash	0·75	
and chloride of sodium	0·53	
Insoluble siliceous matter		29·11
		100·00

*Containing nitrogen	0·69
Equal to ammonia	0·84

	£	s.	d.
1 ton of the Rochdale manure contains 17 lbs. of phosphate of lime, worth at 1*d.* per lb.	0	1	5
17 lbs. of potash, worth at 2*d.* per lb.	0	2	10
Nitrogen equal to $18\frac{3}{10}$th lbs. of ammonia at 8*d.* per lb.	0	12	$2\frac{1}{2}$
	£0	16	$5\frac{1}{2}$

For the true value, see page lxiii.

Mr. Alderman Taylor in a recent return (1876) set forth that a population of 52,000 in Rochdale is supplied with 5,644 pails, from which, in the year 1875 was collected 5,398 tons of excreta. This gives about 9·2 persons, and about 19·1 cwt. of excreta to each tub.

The excreta of one person on an average of an entire population is $2\frac{1}{2}$ lbs. per day, or 8·1 cwts. per year, which, taking 9·2 persons to each tub, gives 74·52 cwts., or 3 tons 14 cwts. per pail; 5,644 pails, at 3 tons 14 cwt. per pail, gives 21,024 tons, as the weight due, if the pails are used by the population to which the statement apportions them, so that about one-fourth of the excreta of the 52,000 persons is alone accounted for. One form of reply may be, that for parts of the day the inhabitants are from home, at work, and use other privies, this, no doubt, is an explanation so far as it goes; the statement however gives no indication of such contingency, neither would such explanation be satisfactory if it had been made; as we see that not more than one-fourth of the excreta is accounted for.

APPENDIX No. IV.

THE LIERNUR PNEUMATIC SYSTEM OF TREATING EXCRETA.

In September 1875 we visited the cities of Leyden and Amsterdam.

LEYDEN.

At Leyden, accompanied by the town clerk (Mr. Kist) and one of the aldermen, we inspected the pumping station and in answer to our inquiries received the following information.

The city of Leyden is built upon about 50 islands formed by the affluents of the Rhine. Here a population of about 39,869 is congregated in about 5,000 houses. Their potable water is derived chiefly from the canals which intersect the city and in some cases at points near the outlets of drains from the houses. These canals are, in fact, not only the main sewers of the city, but the main source of water supply; a large quantity of solid refuse is also discharged into them; this has to be constantly dredged out, and the operation conducted in hot summer weather is very offensive.

The house property drained by the Pneumatic system stands upon an area of about four acres, and consists of a poor-house an orphan-asylum and 146 private houses adjacent thereto, situated at the south of the city in Saint Jakob's Gracht, Koerpoort Gracht, Keifhoet, Gaarmand, Hoef Straadt and Raamsteeg, near to a large canal, and this district is occupied by a population, including 140 inmates of poor-house and asylum, of 1,197, who have in use 156 Pneumatic privies. The entire cost of the works *i.e.*, erecting pumping-station, providing 8-horse power steam engine, air pumps, 5,560 feet of 5-inch cast-iron pipes laid under streets from pumping station to the houses, cocks, valves, and funnels to privies, was 2,833*l.*, or 18*l.* 3*s.* 2¼*d.* per privy, or 2*l.* 7*s.* 6*d.* per head of population. The costs were defrayed by the city council, and we were informed by the town clerk that the council did not propose to extend the system because of the great expense. The engine at the pumping station is only worked for three hours on four days in each week for the purpose of removing the excrements to the pumping station, and the yearly cost of this service, including labour of engine-driver and two turncocks, fuel, and materials was in 1872 333*l.*, or 5*s.* 6¾*d.* per head; in 1873 182*l.*, or 3*s.* 0¼*d.* per head, and in 1874 259*l.*, or 4*s.* 3¾*d.* per head of the population using this service. In May 1875, Mr. M. D. von der Hoef of Oegstgeest near Leyden, entered into an agreement with the Municipal Council to send by his barge, when the canals were open, twenty-five 36-gallon old petroleum barrels twice every week to the pumping station to remove the fœcal matter, and to pay for it at the rate of 2½*d.* per 32 gallons; but, in winter, when the canals are frozen, the municipality are to pay the carriage to his farm, which will amount to 5*d.* per 36-gallon barrel.

We visited the dairy farm of 40 cows belonging to Mr. M. D. von der Hoef and saw the mode he adopted of distributing the fœcal matter over his farm, the greater part of which is in meadow, a fine rich loam on a sandy subsoil; six of the barrels unloaded from the barge were placed on a low wheel dray, and drawn by one horse about a quarter of a mile on to the meadow required to be irrigated; the contents of three of the barrels were emptied into a tank on four wheels, which was then drawn about by a horse from place to place as required, whilst a man with a scoop threw the excrements, which were very dilute, over the meadows. Three men are engaged two days a week in removing the fœcal matter from the city and applying it to the land, and this cost 16*s.* per week, in addition to the sum paid for it. In reply to our further inquiries Mr. van der Hoef said: "I don't know what I shall do with the excreta in

winter (two months) when it is frozen in the barrels. I suppose I must store it in the shed until the frost has gone; I have only had the manure since May 1875, and my experience of its utility is very limited."

AMSTERDAM.

Amsterdam.—In this city we inspected three of the principal blocks of buildings drained by the Liernur pneumatic pipes, and also saw the working of the system. The Director of Public Works (Mr. J. Kalff) and Mr. J. G. van Niftrik, Stads Ingenieur, accompanied us and gave to us the following information.

Amsterdam lies at the influx of the river Amstel into the Y, as this arm of the Zuider Zee, which forms the harbour is called. Canals of various sizes intersect the city in several directions, and divide it into about 90 islands which are connected by means of nearly 300 bridges. It has a population of about 286,932 living in about 30,000 houses. The entire want of spring water at Amsterdam is a serious disadvantage to so large a city. The houses are provided with cisterns for rain-water, which is used by the inhabitants for culinary purposes. The potable water is obtained from a gathering ground situated in the Dunes 13½ miles from the city, impounded in a reservoir which has an area of seven acres, and a mean depth of 20 feet. The city was formerly supplied from a small river, the Vecht, abstracted at a point above Weesp, about nine miles from the city by means of "leggers," or water-barges, constructed for the purpose, and are still used in exceptionally dry seasons.

The whole of the sewage flows into the river and canals, which here, as at Leyden, are the main sewers of the city. The drains for carrying off the fæcal matter and house refuse are mere surface-carriers continued along the edge of the footpaths in the streets; covered over with deal flaps hung to the timber kerbing, and discharging into the river and canals, some of these drains were in a very foul condition.

The Amstel is nine feet in depth, the canals generally three to four feet only, and the thick layer of mud which covers the beds is stirred up by the passing barges Dredging machines are engaged in removing this mud, and this is found to be a nuisance in hot weather. In order to prevent the entire stagnation of the large volume of sewage poured into the river and canals, a supply of clean water is introduced through a sluice into the canals from the Zuider Zee.

The Pneumatic System as described by the Director of Public Works.

The Pneumatic system was, on the date of our visit to Amsterdam, in operation in nine blocks of buildings, partially in the old city and partially in the new town, situated at—

(1, 2). Marnixkade,
(3.) Willemstraat,
(4.) Pieter Cornelisz Hoofstraat,
(5.) Stadhonderskade and Jacob van Campenstraat,
(6.) Bonwkas,
(7.) Focke, Simonszstraat (formerly Looÿersloot,)
(8.) Sarphatistraat and Audueszkade, and
(9.) Heerengracht.

The blocks 1, 2, and 3 are brought in to communication with a central

tank placed between blocks 1 and 2 at the waterside; this tank is distant from the farthest privies in the blocks Nos. 1 and 2 311 metres, and from those in block No. 3, 288 metres. The pipes in block 3 are syphoned under the Lÿnbaausgracht canal.

The length of the pipes in block No. 4 is 725 metres from the extreme point to the canal side, where there is a steamboat.

The greatest length of pipes in block No. 5 is 344 metres; in No. 6, 467 metres; in No. 7, 355 meters; in No. 8, 567 metres, and in block No. 9, 18 metres. The pipes are all of cast iron, and for the blocks 1 and 2 their diameter is 6 inches; the joints are made with caoutchouc rings and tightened with iron collars. In all the other blocks the pipes are five inches in diameter and the joints are made in the ordinary manner with lead.

The depth of the pipes beneath the ground varies from 0·50 to 1·50 metres; the greatest depth is the syphon under the Lÿnbaausgracht canal which is laid at a depth of nearly three metres.

A special form of privy-funnel is connected with the "fall" or soil pipes by syphons; there are about 1,100 of these "privies" in use, by 4,837 persons.

The system was applied in 1871 to blocks 6 and 7, in 1872 to blocks 1 and 2, and to the other blocks in 1873 and 1874.

In block No. 7, the city council not only paid the cost of the works inside the houses, but also the cost of the works in the streets; in the whole of the other blocks, however, they only paid the cost of the works in the streets. The entire cost of the work is therefore not known, but the Director of Public Works informed us that he estimates the cost of the works in the streets at 2*l.* per head of the population, and the cost of the works inside the houses at a like sum, or 4*l.* per head, but the costs of these latter works will greatly depend on the numbers of floors and numbers of privies in each house.

With the exception of the above-named block, No. 7, the work inside has been executed by the owners, and no control has been exercised over the work done; this latter circumstance is much to be regretted, because the good working of a whole system of pipes depends on the proper execution of the works in the several houses. There are consequently places where, from defective house fitting, the system does not work well, so that in some houses the privies do not act as intended.

Supervision of any new work within the houses is now enforced.

Further Statement by the Director of Public Works.

The Director of Public Works in a letter addressed to us, dated 29th September 1875, says:—

"We are afraid that we shall not be able to get rid of the whole production of excreta collected from blocks 1–9; it is evident that this cannot be done when the canals and rivers are frozen over, because the transport, per cart, for great distances cannot pay for refuse stuff of that worth and weight."

"Fixed engines do the work of blocks Nos. 1, 2, 3, and 8, but all the other stations are worked by moveable engines; a steamboat, if the canals are not frozen."

"Many stoppages have occurred in the street-pipes; and in some cases it has been found necessary to disjoint the pipes to remove the obstruction, when it has taken occasionally as much as three days to remedy the defect; stoppages have been caused by towels, rags, chignons, pieces of meat, and solid substances thrown into the privies. Ball-valves are used in blocks 1, 2, 3, 6, and 7; these balls, on becoming fixed, cause very

frequent but less important stoppages. The total quantity of excreta removed weekly is about 75 tons, and two thirds of that quantity is water ; enough to prove that the prescribed rule, not to throw water into the privies, is not observed, but not enough to give ground for the opinion that all the slop water from the houses is thrown in."

"Until September last (1874), the fæcal refuse was leased by a gentleman farmer residing at some distance from the town who paid for each ton delivered at his farm 4*s.*; the delivery of it cost the municipality 3*s.* 2*d.* per ton, and although the lease did not terminate before the end of 1875, the gentleman disengaged himself some months before the expiration of the term. He said the stuff was too dilute."

"The cost of working amounts to at least 5*s.* per head per year, but what we are doing here with our eight different points of working ; using steamboat and locomotive, is not a fair trial of the costs of working a good application of the system, as, take a compact block of the town, say 50 or 100 hectares, with a fixed engine in the centre, and the working costs would be reduced."

"Besides these costs of working you have to add the interest on the cost of the plant."

"Though we have not had a very severe winter since the Liernur system has been in operation, I think no other serious difficulty would be met with than the freezing of the diluted fæces in the barrels, which would make it impossible to get the stuff out of them. Captain Liernur pretends that the fæces ought not to freeze, but we know by experience that the diluted fæces do and the Pneumatic system does not produce other than diluted fæcal matter."

"To get rid of the stuff we have sold it, in the spring of this year, for 3*d.* and even for 2*d.* per barrel of 340 lbs. to different customers. This did very well till June or July, when we could not sell any more, the farmers not wanting manure before the end of the first harvest. We hoped to have the same customers in August, if not before, but until now, the end of September, we have had but few of them. They write that they will return in the spring, and we hope and think so, but you see it is a poor bargain to sell only a few months in the year when you are producing the whole year. So that the question of getting rid of the stuff at a fair price wants still a solution."

"Captain Liernur pretends that a former administration has paid no attention to the conducting of the house and kitchen water in separate pipes, and even his friends have insinuated that for that water there was no separate sewer at all, so that people were *obliged* to throw the water into the Pneumatic pipes. Now, this is not the case, where the Pneumatic system is executed at Amsterdam, there is in the streets a separate system of drains for the rain and house water ; in and near each house there are sinks, and in each kitchen there is the kitchen-sink or sewer ; but Captain Lieurnur is so far right that in the blocks Nos. 2 and 3 there are privies *in* the kitchen ; this is an abominable arrangement, and besides is a constant allurement for the cook to throw water into the privy instead of into the sink, the small dimensions of the waste pipe does not afford the servant such a good occasion for emptying her pail at once. However, Captain Liernur goes farther and deems it now necessary that on each floor, in or near the privies there should be a separate sink, the waste-pipe from which should be as large in diameter as the soil-pipe of the privy, so that there should be not the least inducement for the servant to prefer the privy to the sink. Captain Liernur has had occasion to prescribe all these new arrangements, for it is he who projected all the contrivances inside the houses. That

he did not prescribe proper fittings in the first instance is his own fault, and it is a poor excuse for him now to say that this was the mistake of the administration, who had nothing to do with the inside fittings, as they only paid for the works in the streets.

"But what is much more serious and to the point is this, that what Captain Liernur proposes now, and what is partly done at Leyden, is to my mind in flagrant disaccordance with the principles of the whole system; there is not the least doubt but that if there were more convenient ways of getting rid of the house and wash water of the upper floors than by the privy, this (the privy) would not be used, as it is now, for the removing of waste house water; but it is not the less evident that the privy, in that case, would *not* receive all the fluid excreta of the night, which would find its way with the wash water down the more convenient sinks. Captain Liernur himself states that perhaps *now and then* the contents of a chamber-pot will be thrown into his privy-pan, as into a sink.

"Now the quantity of the fluid excreta of the night (the blowing off at night and morning before going to sleep and before rising) is estimated at 4/7th part or more of the fluid excreta of the twenty-four hours, and as the fluid excreta does contain seven times as much nitrogenous or putrescible substances as the solid excreta, it results thereby that the making of convenient sinks in or near the privy closets includes the gathering of, about one half of all the excreta in the expensive iron pipes, and the losing, at least the other half of these substances, down the sinks and the earthenware pipes, which are not destined for that use, so that there is the danger of infection, which the whole Liernur system professes to remove.

"In the 'Times' of the 23rd of September 1874, it is estimated that with the Liernur system waterclosets can be used without losing any of the agricultural value of the excreta by dilution. Now this may be the theoretical notion, but practically it is the reverse. Suppose the privy closets combined with the Pneumatic pipes, even arranged as Captain Liernur proposes, so that only a limited quantity of water is thrown in the privy closet each time it is used. He estimates the needed quantity of water at 2 lbs., and I cannot estimate it less; it is known that, on the average, each person uses a closet, or urinal, four times in the twenty-four hours, children do this more frequently. Each time the closet is used, however small the quantity of the excreta may be, 2 lbs. of water is to be thrown into the closet; that is, 8lbs. in the 24 hours. On the average, the production of excreta per head is $2\frac{1}{2}$ lbs. in the twenty-four hours; thereby it results that, even if the contents of the chamber-pot be thrown away elsewhere, the excreta will be diluted with four times their weight of water; that is, you will obtain a ponderous mass of no practical agricultural value; as is proved in Amsterdam, where the diluting with only twice the weight of water suffices to make the manure very difficult to sell at any price, because of the bulk and cost of removal, and in winter of storage. For the same reason, it is not true, what is said in the same paper, the 'Times,' that the system is independent of the house-dwellers, and yet it is stated that these by their inadvertence or mismanagement cause the city much loss by throwing water down the privy, or solids, such as towels and chignons, whereby stoppages occur in the pipes, as is proved by experience. It is said, that the management is in our hands, and that perfect working depends a great deal on the goodwill of the householders and their servants, and a strict observance of given rules, which are in practice grossly neglected. We, however, in Amsterdam dispute this, as we consider that the fault is in the system. We do not think

stoppages can be prevented, neither do I believe that there is a city in the world where the Pneumatic system can yield a good return upon the capital employed. I, however, for my part, don't think this necessary if the hygienic object of the system can be obtained, but I disapprove very strongly of misrepresentation; the system does cost a great deal of money, and therefore must burden the town with taxes.

"In Amsterdam the system is not used by more than some 6,500 inhabitants."

"It is not true that the expense of the Pneumatic system in Amsterdam has only been at a rate of 2*l.* per head of the population, including the changing of the existing privies and all other charges. The 2*l.* per head may suffice for the outside, or street works, if you can use the existing sewers for the rain and house water; but you may reckon at least another 2*l.* per head as the average for the changes inside the houses; or, in the whole, a cost of 4*l.* per head of the population. Of course in new quarters there is no changing; and, therefore less outlay, and the costs of changing in the existing parts of the town differ greatly in various quarters by the construction of the houses, the number of floors, and the number of the house-dwellers. I think, however, that even with a well-arranged system the annual working expenditure for a town of 20,000 inhabitants will exceed 2,000*l.* I know very well that what we are now doing at Amsterdam, though it is done under the advice of Captain Liernur, is not in all respects a fair trial as to the annual expenditure, because the system costs yearly about 1,200*l.* for not quite 5,000 inhabitants; this amount can be lessened much in new works, by not following our example of constructing works in eight different and separated parts of the town, as a compact arrangement would be more economical. However, I think that, basing my opinion on practical experience, it would cost not less than 3,000*l.* a year to carry out the system completely in a town of say 20,000 inhabitants. This would not however signify much if really the promised 10,000*l.* were to be got for the fæcal waste, as stated in the 'Times' newspaper, but we did not get more than 2*d.* for 340 lbs., and the party who had leased the whole for that price abandoned the bargain as soon as he could do so, on the pretence of the excremental matter being too dilute. Now suppose we had sold twice as much water as excreta, then we should have got for the production 1*s.* 6*d.* per head per year, and this for 20,000 inhabitants would be 1,500*l.* a year. If we could realize such an income we should think ourselves very lucky, and we hope the market we are trying to find would continue such an income. The pastures round this town are used principally, if not exclusively, for milch cows, and these meadows don't want such rank manure; but it is not less true, that as long as the canals are not frozen, there is no town situated so advantageously as ours, as, from every point of the city, we can convey, per vessel, this production to other parts of the country.

"I don't think there can be obtained any financial result by the making of poudrette, but we have no experience of that as none has been manufactured here. The city of Dordrecht will, it is said, try it in a few months. It is a great fault of Captain Liernur and his friends to awake high expectations about the returns to be expected from the sale of the manure.

"If there is any worth in the system, it is in the hygienic side of the question, and I think that, in some cases, it may do much to lessen, if not fully to remove, a great existing nuisance. But I don't think it possible to apply the Pneumatic system, for instance, to London."

Badhoeve Farm, Haarlemmermier.

We visited the farm of Mr. J. P. Amersfoordt, at Badhoeve Haarlemmermeer, and that gentleman courteously gave to us the following information:—

"My farm has an area of 450 acres, of which 325 acres are meadow, 75 arable, and 50 timber and plantations; the soil is a rich loam upon a sandy subsoil. I keep a dairy of 45 milch cows, also about 100 oxen and young stock, and about 300 sheep. From January 1873 to December 1874, I received, from Amsterdam, the fæcal matter collected by the Pneumatic system, and the following account gives the quantity delivered each month, and the amount paid for it:—

Months.	Weight in Kilogrammes.	Price paid in Guilders and Cents.
1873.		
May	111,180	300·18
June	154,730	417·71
July	119,420	322·43
August	94,255	254·48
September	146,490	395·52
October	166,615	449·86
November	146,170	394·65
December	198,135	534·96
1874.		
January	215,740	582·49
February	168,100	453·87
March	230,765	623·06
April	224,345	605·73
May	230,285	621·76
June	250,685	676·84
July	305,440	844·68
August	364,130	983·15
September	143,530	I refused to have any more because it was so dilute, and the carriage was excessive, and it was delivered on to the farm during these four months without any charge being made for it.
October	363,275	
November	296,430	
December	91,670	
Total	4,021,390	

Or about 4,022 tons of fæcal matter delivered in 20 months, for which I paid the municipality 905*l.* or at the rate of 4*s.* per ton.

"The excreta was sent to me by barges, and about 100 old petroleum barrels, holding about 36 gallons each, were delivered every day, Sunday included. On arrival at Badhoeve, the barrels were unloaded and carted on to the farm; the contents of five barrels were then emptied into a liquid manure-cart, and drawn over the meadow required to be irrigated; this method of applying the excrements did very well in fine weather, but after rain the surface of the meadows was so soft that it was very difficult to get the cart over the land, even with a smaller load, (*i.e.*, the contents of two barrels at a time.) I found after using the excreta for some time, that the meadows gave little or no indication of being manured, and on my complaining to the municipal authorities of Amsterdam, they caused samples of the fæcal matter to be analysed by Mr. J. W. Gunning, Professor of Chemistry of the University of Amsterdam, and the following are the results:—

"In six samples of excreta, each sample being the mean of a series of samples collected during one week, we detected in each case nitrogen

per cent., No. 1,—0·348; No. 2,—0·366; No. 3,—0·400; No. 4,—0·349; No. 5,—0·336; and No. 6,—0·618, the mean of the six samples being —0·403.

"The municipality had guaranteed that the fæcal matter should contain,—0·9 of nitrogen per cent. After this I declined to take any more of the manure. The barrels contained all kinds of refuse which had been emptied into the privies, such as old rags, shoes, broken utensils, and corks. I should be willing to take the sewage; that is, the whole of the solid and liquid excrements combined, if regularly delivered on to my farm by sewer-pipes, but not in the irregular manner in which it has been delivered. The cost of the fæcal matter and the cost of distributing it over a portion of my farm came to nearly 4*l.* per acre per annum for the land thus manured. Butter being the chief produce of the farm, my milch cows did not graze the meadows which were manured with the excreta, because I knew by experience that it would have given a taste to the butter; and we, in this district, are celebrated for making very fine butter; but oxen, young stock, horses, and sheep fed in these meadows on which the excreta had been put preferred that to any other portion of the pasture.

"The whole of the farm is under-drained to a depth of three feet, the drains are 30 feet apart, and the drain-pipes are so arranged that they can be used for upward, or subsoil irrigation, the water being introduced by means of a syphon laid under the adjoining dam."

Abstract.

These Dutch statements show that the first cost of the pneumatic apparatus is very great, being at a rate of 4*l.* per head of the population, and that the annual expenses are at a rate of 2*s.* per head. This is all in excess of ordinary sewers and drains, and ordinary scavenging. The income, it will be noted, is at present unsettled and uncertain.

The Director of Public Works at Amsterdam, on page 66, states that in his opinion it would cost yearly 3,000*l.* to carry out the Pneumatic system in a town of 20,000 inhabitants, and that the apparatus would cost not less than 4*l.* per head, or a total of 80,000*l.*, which at 6 per cent. is 4,800*l.* per annum, or an annual total of 7,800*l.* If, therefore, London, with its 3,600,000 inhabitants, were to have its excreta removed by this system at a proportionate cost, the annual expenditure would amount to 1,404,000*l.*, and all other main sewerage costs would remain as at present.

PARIS.

The city of Paris has a population of 1,851,792.

Formerly the southern part of the city drained into the Seine and Bièrve; and the northern part into the Seine and Menilmontant; but the whole of the sewage has been intercepted, and now flows to a point at Clichy when it is pumped through iron mains four feet in diameter, carried by the Pont Clichy across the river Seine to Asnières; and thence it flows over a portion of the plain of Gennevilliers. To this land also is conducted, through iron pipes laid beneath the carriageway of Ponts St. Ouen and St. Denis, a considerable volume of sewage from the districts of Montmartre, Belleville, St. Owen, and St. Denis.

The sewerage system of Paris consists of seven principal and fifteen secondary collectors. On the right bank of the Seine there are three principal collectors, converging to a chief one under the Rue Royale ; (which conveys the sewage to Clichy) ; there are also three on the left bank of the river, and these communicate, with the chief one, by means of two syphons under the Seine.

The chief collector is 16 feet in height, 18 feet in breadth, and about three miles in length ; the aggregate length of the main-sewers already completed is about 354 miles.

The Plain of Gennevilliers is well adapted for sewage utilization, as it consists of a light open soil on a gravelly subsoil of considerable depth ; and it, therefore, serves the purpose of a natural filter ; but at the date of our visit, in September 1875, only about 400 acres were under irrigation.

In outline, the Plain very much resembles, although on a larger scale, the sewage meadows of Carlisle bounded by the Eden ; and also the Kendal sewage farm bounded by the Kent.

The principal main sewage-carriers are formed of brickwork, and are 7 feet wide and 3 feet deep, the branch-carriers being 3 feet 6 inches wide and 2 feet deep.

The daily volume of the sewage of Paris is equal to 343,700 tons, but only a limited portion of this (*i.e.*, about 28,000 tons) is used on the land required to be irrigated, the remainder flows into the river Seine at Clichy.

The whole of the solid excrements of the population are not allowed to go into the sewers ; these and the contents of cesspools are collected and removed to the Forest of Bondy, and are there manufactured into poudrette ; but as the streets are cleansed daily and the droppings of horses and surface dirt are swept and flushed through the gullies into the sewers, the sewage contains a large quantity of solid matter, not only in suspension but also in solution.

In 1869 the municipality of Paris, having laid down the carriers, sub-carriers, conduits, and pipes for distributing the sewage over the land at Gennevilliers, conceded to the owners, and also to the lessees of the allotments, the free use of it until 1880, after which time, if they continue to use it, a rent is to be paid. At first there was a great prejudice against the use of sewage as a manure, and also the produce grown by its aid, but this has gradually died out, and the number of allottees who use the sewage increases every year, and the owners and occupiers are much pleased with the result.

The allotments are very numerous, and are let on lease for terms varying from 3 to 15 years.

The crops grown under sewage-irrigation have been a perfect success ; they comprised absinthe, artichokes, asparagus, beans, beetroot, cabbage, cordon, carrots, celery, chevil, chicory, cohl-rabi, cucumbers, leeks, melons, onions, parsnips, peppermint, potatoes, pumpkins, spinach, tomatoes, turnips, lucerne, clover, Italian rye-grass, mangolds, wheat, oats, and Indian corn.

The market-garden produce yielded very abundant crops. The asparagus is grown in nursery-beds as plants, and afterwards sold to gardeners, who force it for use of consumers. The Indian corn was of exceedingly luxuriant growth, 9 to 10 feet high. The potatoes gave a very good crop ; the sewage is applied to the land before planting potatoes, and not to the growing crop, except in drought. The Italian rye-grass and lucerne yielded five cuttings for hay and two cuttings green for cattle feeding. It is found that the application of sewage to lucerne more than doubles the weight of the crop. A meadow of natural grass (principally cocksfoot) under sewage treatment, yielded three crops of hay in the year, and these realized 15*l.* 15*s.* per acre. Application of

sewage to young fruit trees has also been very successful. The average yearly rainfall is 20 inches. The hot and dry plain of Gennevilliers is capable of absorbing a very large volume of sewage, especially in the summer season. It is found that the sewage does not readily freeze, and therefore can be applied continuously to the land. The available area of land at Gennevilliers is insufficient to receive the daily volume of the Paris sewage, and we were informed that it is in contemplation to extend the main conduit to St. Germain, and to irrigate the land lying on the edge of the forest, and also the forest itself if necessary.

The effluent water after percolating through the gravelly subsoil flows into the river Seine, and at the date of our visit it was clean, bright, and inodorous.

BERLIN.

The sewage at present flows into large open channels or gutters by the side of the footpaths in the streets; these are principally lined with stone or bricks, and, where they cross the streets, are covered with deals; the gutters are swept by the scavengers daily, and the solid refuse removed therefrom, but the liquid flows from thence into the river Spree and the canals.

A system of sewers is being carried out on the English plan, and for this purpose the city has been divided into five drainage districts, with a separate pumping station to each. The main and branch sewers are built of brickwork, egg-shaped in form; they vary in height from 4 to 7 feet; the subsidiary sewers are formed of stoneware-pipes of of from 9 to 24 inches in diameter. The sewers are chiefly laid at gradients of 1 in 500, the flattest being 1 in 2,400. Each of the five pumping stations will have six engines of 60 horse power each, four "Galloways" boilers, and two locomotive boilers as auxiliaries for getting up steam in emergency. The total pumping power will be 1,800 horse. Each of the pumping stations is estimated to cost 50,000*l.*, and the entire cost of the sewerage works, pumping stations, and pumping mains is estimated at 2,000,000*l.* sterling.

No. III. works are nearly completed, and we were informed that the sewerage works in this district would be finished, and pumping at this station commenced in 1876.

The sewers will receive, in addition to the sewage proper, the whole of the rainfall upon the houses and streets; arrangements having been made by which, in heavy storms, more than 4/5ths of the flood-water will escape by specially provided overflows direct into the river. The average yearly rainfall is 22 inches.

The municipal council propose to utilize the sewage in irrigation, and to enable them to do so, they have purchased, at a cost of 400,000*l.* (or about 100*l.* per English acre) 2,000 acres of land, a sandy soil, lying to the north, and 2,000 acres to the south of the city, distant there from about 10 English miles, and these farms are being prepared to receive the sewage.

The sewage will have to be pumped through cast-iron mains, two to each farm, each 3 feet 6 inches in diameter, to a height of 130 feet.

It is estimated that the mean daily volume of sewage thus to be dealt with will be 28,000,000 of gallons; of this volume 16,000,000 of gallons will be delivered over the North Farm, and 12,000,000 of gallons over the South Farm; and, from the nature of the soil, it is expected that the whole of the sewage will be absorbed and completely oxidized.

Subsidence-tanks will not be constructed, but the sewage will flow direct from the pumping-main into the carriers, and thence over the land required to be irrigated.

The estimated yearly cost of pumping the sewage is 12,000*l.*

One of the pumping-mains is already laid to the South Farm, and

upon this farm it is proposed to grow Italian rye-grass, roots, tobacco, all kinds of esculent vegetables, but no cereals.

It is also proposed to lay down a branch line of railway from this farm to Marienfelde Station, which is about two miles distant, and by this means to bring the grass and vegetables into Berlin, and, if a ready sale is not found for them, the municipal council propose to keep a dairy of milch cows at their farm, and convey the milk to the city; they also propose to carry on the farms until they are in good working order, and then to let them with the sewage; but they do not propose to sell sewage *en route*, as they expect to make a better bargain by letting the farms and sewage together.

APPENDIX No. V.

EPIDEMIC DISEASE.

Epidemic disease will probably be a means of bringing about the greatest modern improvements in civil and social life, as inquiry and investigation make it more and more apparent that neglect of sanitary requirements in past ages has tended to generate plague and pestilence; and, in modern days, to bring about their occasional revival, with typhoid and cholera added. There are in the cycle of time wholesome and unwholesome seasons, periods of excessive wet, long continued generating malaria, and seasons of parching drought producing famine, the depressing influences in both cases lowering the public health and so exposing the human body to other influences immediately surrounding it which aggravate disease. Wet seasons deteriorate vegetation, and tend to produce disease in animals, so that the food of man becomes unwholesome; dry seasons reduce the produce of vegetation or destroy it altogether, so that man and beast perish. These influences should not be left out of sight in considering causes of disease, neither should they be made too much of; that is, excess of disease should not in all cases be imputed to climate, to seasons, or to the weather, if other causes more potent and deadly can be discovered and which causes can be removed. There are vague notices of great epidemics in remote ages in Ethiopia, Egypt, and India; notices more in detail of the plague in Athens 430 years before Christ; and there are histories of the Middle Age pestilences, plague, sweating-sickness, and black-death, with our modern reports on typhoid-fever and cholera. That which we know of parts of Asia and Europe as to the causes of disease we may infer of India, China, and the other inhabited portions of the surface of the globe; namely, that aggregated populations living amidst filth, devouring unwholesome food, drinking impure water, and living immoral lives, suffer from virulent disease, consequently existence is unwholesome, miserable, and short. Some of the prime causes of disease may be inferred from descriptions of towns, houses, and domestic habits and modes of living during the Middle Ages. Towns were crowded on to the least space possible to afford means for fortifications, the streets were narrow, the houses projecting storey over storey so as to shut out sunlight and diminish the circulation of air, the streets were unsewered and were irregularly paved with large and small boulder stones; if there was a gutter it was down the centre, and over the surface filth from the adjoining houses was scattered and lay there till it rotted. Within the dwelling houses filth also abounded. "The basement floors were mud, over which, in those of the better classes, were spread straw or rushes, and on to which went urine of animals and man, spittle, vomit, sloppings of beer, scraps of meat, bones, refuse from fish, and other filthiness not to be named, which were never thoroughly cleansed, the accumulations going on through long intervals." Such is a brief description of muni-

cipal neglect in England about the time of Henry the VIIIth. A student need not, however, trouble himself to read history to learn how men consented to live amidst filth and neglect of all sanitary precautions in past ages, as in these days of rapid communication he may within the range of Europe visit and inspect towns, dwellings, and populations existing not very much if any below the horrible conditions described by the old historian; but even in Great Britain at this day the description may be accepted as partially true of vast masses of the populations resident not only in the slums of our great cities and towns, but also in our rural villages, the Common Lodging Houses Act and the more recent Artizan and Labourers Dwellings Act having, however, been passed to provide remedies.

In 1848 there was passed the Public Health Act, consolidated into the Public Health Act of 1875, and under this latter Act sanitary work is proceeding. The prime block to more rapid progress being dread of local rating and ignorance of the cost of continued neglect.

As there is no value without human life it follows that healthy human life must be of most value, and consequently that any rates which are necessary to secure health and long life must be worth providing. Past history shows that disease in most horrible forms has from time to time destroyed populations living amidst filth indescribable of their own making. Recent inquiries show that modern diseases of malignant types, such as typhus and cholera, generate out of putrid refuse and gross neglect of sanitary works and operations. Modern civilization aggregates populations, and necessitates modern sanitary improvements, and that form of improvement will be best which permanently produces the most favourable results at the least pecuniary cost.

In cleansing towns, fluid and solid refuse has to be removed; its removal must, therefore, be specially provided for. Rain-water may in some cases flow over the surface by natural channels, and in other cases by channels formed for the surface-water. Towns require to be scavenged, and the solids, ashes and vegetable refuse, have to be removed by carts. Human excreta must also be removed, either in pails or by some other system, wet or dry, or by waterclosets, drains, and sewers. That system which can be established and carried out at the least first cost, and can be worked with the most complete efficiency, will be the best—efficiency implying comfort and wholesomeness. To remove the waste-water from houses and towns as fast as used there must be drains and sewers, as cesspools and water-carts would be impracticable. Through properly constructed drains and sewers water will flow to any required distance, and will wash to the outlet all effete matter from the population at once without any secondary intervention or cost. The sewering of towns and the draining of houses is comparatively new, and there is much imperfect work. There are also numerous mal-arrangements, such as drains and ashpits within house basements, and unventilated watercloscts within the body of the houses and crowded betwixt bed rooms; consequently there are nuisances and fevers, all of which may be prevented. In every form of dry method (there is, however, no such thing as a "dry method") or pail-system, there must be retention, for a time, of the excreta; and there must be fetching, carrying, and returning of the boxes, tubs, pails, or whatever the apparatus may be in which the excreta is received, and the nuisance caused will be in proportion to the time of retention of the excreta within or near the dwelling house, the capacity of the tub or pail to receive the contents without slopping; the regularity, care, and cleanliness in removal; and the treatment of the refuse at the yard or station. If unceasing attention is given to the removal, and rigid cleansing of the tubs and pails at each emptying, and the intervals of removal are short (never to exceed one week), the terrible nuisance of the old privy

and midden system will be abated in some measure; but a week's retention of excreta within or near to dwelling houses must constitute a nuisance. The returns obtained and tabulated in this report show that the cost of tub and pail removal is considerable, and that in no case can the manure be sold to a profit. A rate must, therefore, be levied sufficient to pay the interest on capital and working expenses. The cost of sewering and draining must also be paid for by a rate, but along drains and sewers the excreta will pass without any retention or secondary intervention at once to the outlet, there to be disposed of. Deposition in tanks and chemical treatment of the sewage will remove the suspended solids, but will not produce a pure effluent, neither will the deposited material, sewage-sludge, produce a manure having commercial value. There must, therefore, be a rate in aid to work the best known chemical process as yet tried, or the parties working such processes must lose money. In irrigating land with sewage there is both clarification and purification, in proportion to the strength of the sewage, the volume used over any given area at one time, and the adaptability of the land for the purpose; no mode of treating sewage by deposition and chemicals producing such favourable results. Where sewage can gravitate to land obtainable at its fair agricultural value, there is the least present loss to the community; and, in nearly all cases when the works have been paid for, there will be an available income, a result not attainable by any other known mode of dealing with sewage.

THE PRIVY SYSTEM.

"However perfect in theory the ash-pit privy may be as a means of house scavenging in towns, in practice it has been abominable, and though latterly improved by better organisation and more vigorous superintendence, and the gradual adoption of various ingenious contrivances, it can never be otherwise than highly objectionable—land must get soaked with the drainage water from these cesspools; the air must get fouled with their stinking vapours; the sewers must carry from them to the river that which is most filthy and yet most valuable.

"It was a good suggestion by an opponent of the system, that its friends should picture to themselves the sites of Manchester and Salford, with all their dwelling-houses removed and only the privies left—nearly 60,000 of them—rows, and streets, and crowds of them—scattered about almost as thickly in places as the heaps of manure upon a field that has just received a dressing from the dung cart, each heap, however, no mere deposit by a barrow-load, once a year, but a constant collection and continual soakage of filth, which has for years been polluting every corner to which air or water could have access. Is this the site upon which to build a healthy town? would it not be the first desire of every sensible man to sweep this filth away, to drain and aërate; and, if possible, sweeten this land before a single dwelling-place was built; at any rate, to put a final stop to the process which has accumulated so much dirt, to which, indeed, one may fairly attribute much of the responsibility for the high death-rate disclosed by the returns of the Registrar-General, from the South Lancashire towns. Those returns show that typhoid fever, scarlatina, diarrhœa, and other zymotic diseases, commit fearful ravages amongst the populations exposed to such pestiferous influences.

"The relative polluting effect of sewage from midden towns, as compared with that from watercloset towns, is no mere matter of opinion founded on *à priori* argument. It has been made the subject of direct investigation." (Rivers Pollution Commission Report, Mersey and Ribble Basins, 1870, pp. 28, 29.)

"The proportion of putrescible organic matter in solution in midden

towns is but slightly less than in watercloset towns, whilst the organic matter in suspension is somewhat greater in the former than in the latter. For agricultural purposes, 10 tons of average watercloset sewage may, in round numbers, be taken to be equal to 12 tons of average privy sewage. The average quantity of chlorine in 100,000 parts of watercloset sewage is 10·66, while in midden sewage it is 11·54. This difference is very significant; it shows that, assuming (which is probably approximately the case) all the urine to reach the sewers in both classes of towns, a larger number of individuals contribute to a given volume of sewage in midden than in watercloset towns. Chlorine in these cases represents common salt, and the latter again indicates the proportion of the urine in the sewage. The proportion of chlorine, therefore, ought to give the proportion of average individuals (men, women, and children) contributing to each kind of sewage, and from this it would follow that the populations producing equal volumes of sewage in midden and watercloset towns are as follows :—

In watercloset towns - - -	1,066
In midden towns - - - -	1,154

The cause of this difference in the volume of sewage per head of population in the two classes of towns is obviously to be sought for in the somewhat increased quantity of water needed by and supplied to the former."*

THE CONDITIONS of some TOWNS, VILLAGES, and HOUSES in GREAT BRITAIN at this date, 1876.

1. There are towns, villages, and houses in Great Britain entirely without sewers, house-drains, or even common privies ; the condition of the streets, roads, and lanes, indicating to sight and smell the habits of such populations.—See Health of Towns Reports, 1842, and the Reports of the Superintending Inspectors of the Board of Health 1848, Whitehaven for instance.

2. There are other towns, villages, and houses where there are cesspits, cesspools, and privies, for portions of the population ; the privies and ashpits being in all sorts of improper public places, crowded against houses, with some beneath occupied rooms ; and those in open and exposed places having shattered doors, broken seats, rude ruinous cesspits ; the places and all about them being filthy beyond description.

3. There are other towns and districts situate in porous but waterlogged sites, where there are wells and cesspools side by side ; the subsoil-water, according to the season, rising or falling simultaneously in both wells and cesspools, the water of the wells being dangerously tainted by sewage from the cesspool.

4. There are some towns and districts imperfectly drained by rudely formed stone drains, originally made to remove surface-water, but which the inhabitants now use for sewage ; consequently creating a nuisance.

5. There are towns and districts partially sewered and where waterclosets are partially used, the larger proportion of the population, however, still using common privies and cesspits, whilst many of the inhabitants have no sort of privy accommodation provided, but chamber utensils are used by the females ; the yards, roads, and lanes, being fouled by the males and children.

6. There are towns and districts fully sewered upon correct principles, but the houses are not drained, and, as there is no public water-supply, there are only a few waterclosets—common privies and cesspit-middens remaining.

* Extracted from the First and Second Reports of the Rivers Pollution Commissioners, Mersey and Ribble Basins, pages 24, 25.

7. There are towns and districts which are completely sewered, drained, and have a full water-supply. Cesspools and cesspits having been abolished, waterclosets substituted, and the sewage at the outlet being applied to land for agricultural uses. But even in such towns there are grave defects, as neither sewers nor drains are fully ventilated; and many of the waterclosets are situate in improper parts of the house and are also defectively ventilated.

The defects stated in the above seven cases have been described over and over again in the Sanitary Reports of the last twenty-five years, and there has been, and now is, considerable movement to obviate some of the most glaring evils enumerated. But the local authorities, in many cases, shrink from incurring the first costs of main-sewers, house-drains, the abolition of cesspits and privies, and the establishment of waterworks; the substitution of waterclosets and providing land for sewage irrigation. Hence the adoption of patented schemes of various kinds, dry and wet, for the removal of excreta, all of which are costly failures. The prohibition against polluting streams with sewage has also brought in patented modes of dealing with sewage, the inventors professing to purify it, and to make a portable manure out of the sediment which shall have commercial value. Every such scheme, up to this time, having, however, failed even to purify the sewage, as well as failed to pay working expenses by the sale of any manure made.

Sewering, draining, a public supply of water, and scavenging, are necessary to the comfort and health of town communities, and a purification of the sewage outside of the town is necessary to the health of the country, and so far no form of portable apparatus, wet or dry, dry-earth closet, or Rochdale, pail, can dispense with sewers, drains, and a public water-supply. So far, then, all are agreed. The waste water from houses, streets, yards, and manufactures must flow away through sewers to some common outlet; and, as this fluid is polluted by every form of pollution within a town, though excreta is absolutely excluded, it is, in fact, sewage; it must, therefore, necessarily come under any laws and regulations enacted against polluting streams with sewage. These facts are either not appreciated or are not understood by those persons who adopt the various moveable apparatus and work them at so great a cost to the ratepayers. As to the so-called "dry-systems" there is no such system, because all are necessarily more or less wet. The pails do not receive and remove all the urine, as is shown by the returns of the weights removed by the pails used at Rochdale in proportion to the population. Captain Lienur, in his most complicated and costly pneumatic system, does not profess to remove all the urine, but insists upon special provision being made for the reception and removal of waste-water. As side-by-side with his pneumatic privy-pan-closet, he states that there must be a sink for waste-water and the contents of chamber-utensils entirely distinct from his apparatus. This must also be the case with dry-earth closets, as also with moveable pans, tubs, or pails; either on the Rochdale plan, or indeed on any other such system. These facts being so, where is the advantage gained by all the extra intervention, labour, and costs incurred? The pleas used in favour of these several modes of removing excreta are, their advocates say, greater comfort to the householder, extra cleanliness, freedom from nuisance, and absolute freedom from any form of pollution sufficient to cause disease. This most desirable result unfortunately depends, however, upon so much perfection in the working establishments as to prove, practically, to be unattainable. A dry-earth closet in summer, if not attended to, becomes a small cesspit. And this attention involves daily removal, effective cleansing of the box, and renewal of dry-earth. I have seen dry-earth closets most disgustingly dirty through misuse and neglect. The several portable tubs and pails are also liable to similar contingencies

of neglect, as the tubs and pails are at times left too long on the premises, and they then become over full and slop over and flood the surrounding surface with matter most offensive to sight and smell; the removal of the wet tubs and pails is dirty work, as there is frequently slopping over the street-surfaces from the vans during removal, and some of the stores, depôts, or yards, to which the pails are removed are reported to be very filthy and offensive. The mixing and making into manure is costly and does not pay. The removal of excreta in this manner is encumbered with the removal to and from the houses and the depôt by van and horse, so that for each ton of excreta there is at the least two tons of dead weight to move backwards and forwards with all the labour besides the wear-and-tear involved. In the Liernur system the apparatus draws the excreta to the pumping establishment, but from this point it is loaded into barrels for transmission into the country, where, as we learn, it becomes a nuisance in winter, as the tubs freeze and burst.

With respect to the practical value of any of these concentrated manures, that is concentrated when compared with town sewage, it is difficult to arrive at a reliable estimate, as experience so far tends to prove that the chemist's laboratory estimate of value is not accepted by farmers. The mixed excreta, that is the mixture with ashes, reduces the selling price to 2*s.* 6*d.* per ton, and even at this price there are large accumulations during those portions of the year when farmers are busy with sowing, haymaking, or harvesting. In some towns the mixed manure is given. Whatever may be the demand for portable sewage manure in the future, the several modes of manufacture have so far failed to secure for the patentees any profit. The cost of any really effective mode of dealing with excreta should not be sufficient to condemn it, as means of cleanliness, comfort, and health, are worth paying for; and, if the means used are, under all local conditions, the best for that district, or the ratepayers choose to consider them the best, then they must pay the necessary costs. The promoters of these dry-earth and moevable wet-tub and pail processes are not however contented to perfect and advocate their own special schemes, but they condemn all other modes of dealing with excreta in unmeasured terms,—especially the watercloset,—as this, they say, taints alike the atmosphere both of the town and of the houses. With respect to the use of the watercloset, the case may be thus stated, All parties admit that towns must be sewered, and that houses must be drained to remove surface-water and waste-water from dwelling-houses and factories; this being the case, these sewers and drains must be of cross-sectional dimensions sufficient to remove not less than 30 gallons per day, in dry weather from each inhabitant, and the capacity ought not to be less than five times this to provide for occasional rain. All sewers and drains receive more or less of sediment, washed from roofs, yards, sinks, channels, stables, slaughter-houses, cow-sheds, and manufactories, and along sewers truly formed the entire contents pass day by day to the outlet, and where waterclosets are used the entire excreta, solid and fluid, with the contents from the chamber utensils and slop-pail, pass at once silently and imperceptibly with the sewage to the outlet, there to be dealt with under one set of operations, avoiding every form of secondary intervention involved in a use of dry-earth pan and pail. The entire of the excreta, in proportion to the sewage in dry weather being, by volume, as 1 of excreta to from 100 to 150 of sewage; and in wet weather, the proportion is of course much greater, consequently, in every portable form of dealing with excreta by the dry-earth or tub and pail systems, the bulk and weight is formidable, and the removal costly, whilst in the water drainage system this bulk is unimportant, because it is only fractional. With respect to the supposed nuisance and danger arising from waterclosets, proper construction and

use render any atmospheric or other taint within the house absolutely impossible, and the sewage flowing daily in a fresh state from the closet-pans along fully ventilated sewers gives no injurious taint. There must, however, be no drains nor openings into drains within the houses. Sink-pipes must discharge over or into a drain outside, and waterclosets must be against an external wall, connected with a soil-pipe, which is carried above the roof; the upper end to be fully open, and the watercloset rooms must have a day-light window, and fixed means for permanent ventilation to the external air at the ceiling. With such arrangements, and a good supply of water, one of the best waterclosets will work with perfect safety, and may be, what such places should in all cases be—private. The mode of dealing with the sewage, at the outlet, is in no way complicated nor rendered more difficult to deal with by the addition of the excreta from the watercloset; indeed, if the sewage is used in irrigation, it is dealt with to much better advantage; as the fluid is richer by so much manure. Bedford, Leamington, Croydon, and Cheltenham are cases in point, where the entire populations use waterclosets, and the sewage is also used in irrigation for purposes of agriculture.

That waterclosets can be used on the greatest scale by an entire population, is further proved in the case of London, where, for 3,600,000 population there is, on an average, one watercloset to each 5·5 of the inhabitants, or about 700,000 waterclosets are in use.*

The excreta passed daily from London may be estimated at 4,000 tons, and to remove this in tubs or pails to a distance of five miles, would cost about 1,000*l.* per diem, or 365,000*l.* per annum. The daily volume of sewage and excreta of London weighs about 600,000 tons, and this flows along the drains and sewers to the outlet at no cost but that of pumping, which is about 36,000*l.* per annum. In many towns this cost would not be necessary, as the sewage will flow to the outlet, but in every case of the dry-earth tub or pail systems there must be the cost of hand removal and carting.†

EXAMPLES OF SEWAGE IRRIGATION.

Extracted from the First Report of the Commissioners appointed in 1868 to inquire into the best means of preventing the Pollution of Rivers.—Mersey and Ribble Basins.

The information extracted from this rivers pollution report bears so intimately on the questions discussed in our Sewage Report, and the several analyses are so full and complete, that we have considered it

* With respect to waterclosets, soil-pans, and urinals, no watercloset, soil-pan, nor urinal should be supplied with water through a screw-down cock, stool cock, or lever-handle, direct from the water-main, but through a service-box or water-waste preventer.

† The late Dr. Parkes, F.R.S., made exhaustive experiments with disinfectants, and found that it would cost about threepence for the chemicals to disinfect one gallon of putrid excreta, so that the disinfection of 4,000 tons per day of London refuse would cost 11,200*l.*, or at a rate of 4,088,000*l.* per annum, leaving the 600,000 tons of sewage per day (or 219,000,000 tons per annum) untreated. These figures only serve to show the extravagance of disinfectants; as, also, that the small doses of Condy's fluid, or of any other fluid, or solid, passed down sinks, waterclosets, drains, and sewers, can practically have no beneficial effect. Foul drains and sewers can only be disinfected at a cost proportionate to the weight and volume of excreta and sewage in the drains and sewers, and this we see would be enormous; they must be flushed with water. Disinfectants may be used with advantage in hospitals, in sick rooms, and in stables; they may also be used by butchers and by others, but they will be practically useless in cesspools, if only small doses are applied; and it is to this fact attention is intended to be directed. The vestries are only wasting parish rates when they send round carbolic-acid to be poured down street gullies by tablespoonfulls. The foul gullies, drains, and main-sewers, may require cleansing, and if so, should be cleansed by flushing, as a use of chemicals for the purpose will be out of the question, on account of the enormous cost of such applications.

advisable to repeat them, rather than to have incurred the great cost and delay which must have taken place if we had obtained new analyses, which could not in any serious degree have furnished more reliable information than this we have extracted. The questions relative to town-sewage, and the best modes of dealing with it, have been so far exhausted that new experiments are not so much required as condensation of ascertained facts put into the plainest language and the least space. Town-sewage is stronger or it is weaker in proportion to the density of the population, the number of waterclosets in use, and the volume of water with which the excreta is diluted. There are three sources of dilution, as, the volume of water supplied to the inhabitants from waterworks; the volume of subsoil-water which leaks into the sewers; and the volume of rain or surface-water which is admitted to the drains and sewers during wet seasons. In manufacturing districts there may be both further dilution and pollution if all the fluid refuse is admitted into sewers. This is, however, a question for municipal regulation. The extracts which follow are given to show town-sewage in its crude state and after filtration through land:—

1. *The Sewage Meadows near Edinburgh.*—These have long been quoted as an example of the largest produce known to agriculture, yielding grass of a somewhat coarse and "washy" character, but perfectly well adapted for cow food. These meadows cannot, however, be named as a good example of the agricultural remedy for the nuisance created by town sewage; for it is poured over them in such enormous quantity that the soil has not fair play given to it as a cleanser, and the water therefore leaves the grass land still filthy and offensive. Even here, however, we have a remarkable illustration of the purifying power of soil and plant. Thus, on April 16th, 1869, when the early crop of grass was being cut, and the meadow land was in full spring growth, three samples of the sewage were taken, No. 1 being of the water in the *Foul Burn*, as it poured, probably 700 tons an hour, over plot No. 11, on the map of the Craigentinny Estate. No. 2 was taken at the foot of this same bed, the water having poured at that rate in half an hour over less than an acre of land. No. 3 was taken at the foot of beds Nos. 45 and 46, the tail water of No. 11, which poured on at their head, having in the meantime taken about an hour to traverse one and a half acres of land. This sample represents the water of the *Foul Burn* as it flowed into the sea. It was not by any means clean, but how much of its filth had been removed during irrigation by the action, for an hour and a half, of two and a half acres of land on many hundred tons of very foul sewage is plain from the following table:—

RAW AND EFFLUENT SEWAGE.—EDINBURGH.

RESULTS OF ANALYSIS expressed in parts per 100,000.

Date and Number of Sample.	Total Solid Matters in Solution.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrites and Nitrates.	Total Combined Nitrogen.	Suspended Matters.		
							Mineral.	Organic.	Total.
No. 1, April 16/69 -	62·20	6·106	3·613	9·510	0	11·445	11·32	28·08	39·40
„ 2, „ „ -	65·50	4·797	2·086	10·579	0	10·798	9·76	16·64	26·40
„ 3, „ „ -	51·60	3·340	·682	1·989	0	2·320	1·28	4·24	5·52
No. 4, April 17/69 -	55·00	5·061	2·842	7·865	0	9·319	28·72	29·88	58·60
5, „ „ -	54·80	4·061	1·988	3·100	0	4·541	5·56	7·40	12·96

On the following day, after a night's rain, when the sewage therefore was more dilute, a sample, No. 4 in the above table, was taken from the *Foul Burn* at Lochend just as it left the pumps, at the rate of about 20 tons an hour, pouring over a plot of Italian ryegrass, 40 yards wide and 44 yards down the slope. It was taking about an hour to traverse this plot of one-third an acre. A second sample, No. 5 in the above table, was taken at the foot of this plot. The composition of these samples is given above; and comparing No. 1 with No. 3, and No. 4 with No. 5, the cleansing agency of the soil, however incomplete, is very apparent. In point of fact, more than three-fourths of the whole filth, soluble and suspended, was taken out of the water of the *Foul Burn* by one hour and a half of irrigation in the first case, and nearly two-thirds of the filth in 20 tons of sewage was taken out of it in the latter case, by irrigation over about one-third part of an acre of the light sandy soil of the Lochend Farm.

The Edinburgh experience, however, is rather one of agricultural profit from the use of sewage than of that perfect abatement of its waste and nuisance, which, in the interest of rivers, we desire to see. This arises from the enormous quantity of the sewer water and the small area of land on which it is used. At Lochend and Craigentinny, on the north and east of Edinburgh, about 230 acres receive the whole drainage of 80,000 people, being at the rate of 350 people per acre. At Grange, on the south side of the city, 16 acres get the drainage of a comparatively small number. At Dalry, on the west, 60 acres or thereabouts receive a very large quantity of filthy sewage, which they are unable perfectly to clean; and there are one or two plots similarly treated on the road to Leith. Here, however, altogether are only 400 acres, whereas the population whose drainage they receive must largely exceed 100,000, and it is not, therefore, surprising that the drainage water leaves the land by no means perfectly cleansed.

The *Foul Burn* which waters the Craigentinny meadows passes first through Lochend farm, where about 20 acres of permanent grass and 8 acres of Italian ryegrass receive as much of it as the tenant chooses to apply. The quantity is, probably, often as much as 10,000 or 15,000 tons per acre during the growing season, besides an indefinite quantity during winter; and, of course, a very small proportion of the filth which it brings down from Edinburgh is deposited here. The stream flows on in almost undiminished foulness to the meadows lower down. In addition to the 20 acres of permanent grass land, there are 12 acres arable at Lochend (of which 8 acres are every year in first and second year's Italian ryegrass) commanded by a self-acting pumping apparatus. A water-wheel, driven by the stream, works a four-fold pump, delivering, when in perfect order, about 1,000 cubic feet per hour, a quantity which, as it works night and day during eight months of the year, corresponds to nearly 20,000 tons, or, even assuming that only half duty is accomplished, is 10,000 tons per acre. In either case it is plain that an enormous quantity is applied—much beyond the needs of the largest possible crop of grass.

The grass of Lochend meadows has averaged, during nine of the spring sales at which it is disposed of by auction, 27*l.* 12*s.* 2*d.* per statute acre. During the past year the highest price attained was 41*l.* 17*s.* 6*d.* per acre; and from that down to 19*l.* an acre has been realised. The Italian ryegrass on the same farm has varied in price from 32*l.* an acre for the first year's cuttings to 25*l.* an acre for the second year's cuttings.

Leaving Lochend the *Foul Burn* pursues its course to the sea on the Portobello side of Leith; but it has for many years been diverted, right and left, to a considerable distance from the original watercourse, and a fan-shaped farm of more than 200 acres, widening out as it gets near the coast, has been thus laid out for irrigation at a cost of about 5,000*l.* This Craigentinny farm includes within its limits land of excellent natural fertility, but it terminates at its lower end in a wide belt of sheer sea sand, which, though now equal in its annual produce to any of the originally superior plots, old men still remember as a barren shore. There is here too a portion of higher land of excellent natural quality watered by a pump, in this instance driven by steam power. The area this year watered thus is eight acres, and as the engine is driven only 300 hours during the six or eight dressings which this land annually receives, the pump, delivering from 60 to 80 tons an hour, does not distribute more than 3,000 tons per acre annually, a quantity which at 1*d.* per ton, if ordinary sewage be taken to be worth so much, many ordinary agricultural crops would easily repay. These eight acres of Italian ryegrass have been sold during the past year at from 25*l.* to 36*l.* an acre,—prices equal to those obtained at Lochend, where four times the quantity of sewage is applied. It would seem therefore, that the enormous surplusage of foul water used at the latter place fails to be of any agricultural service.

In the lower Craigentinny meadows 190 acres receive probably nine-tenths of the *Foul Burn*, and, a night and day waterman being constantly employed in its distribution, it flows constantly over one plot after another; a single dressing of five or six hours being given between the several cuttings of grass to each of the 250 plots, or thereabouts, into which the whole area is divided. The summer's grass of these beds, varying from two to five roods each, is sold by auction to the Leith and Edinburgh cowkeepers every spring, and the maximum value reached last year was 36*l.* 15*s.* per statute acre. The quantity of grass for which such prices are obtained is believed to vary from 50 to 70 tons per acre. And as the means are perfected of distributing the sewage more evenly, and as the subsoil drainage of the land improves, the quantity and price are both increasing year by year. No exhaustion is apparent anywhere. The sewage brings down more than the plants require of every necessary constituent of their food, so that even the poor sea sand is as fertile as the rest, and the land is getting richer year by year, notwithstanding the enormous crops it yields. Taking the average price of the whole 240 acres to be 24*l.* an acre, we have a total annual produce of 5,760*l.* a year extracted by the land and grass from the drainage of 80,000 people, or 1*s.* 5*d.* from each person annually—certainly not $\frac{1}{2}d.$ a ton over the enormous quantity of sewage which is here applied.

But the area is not sufficient to take up the whole of the filth brought down by the water. A much larger extent of crop could be obtained from the use of it if there were any land convenient on which it could be applied, or if there were a sufficient demand for the produce of it. The Edinburgh experience, therefore, must be quoted not as a successful example of sewage cleansed by irrigation, but rather as an instance of the largest produce raised my means of it from a limited area of land.

2. *Lodge Farm, near Barking.*—We turn now to an example of another kind, where the supply of sewage is limited and where the object has been, from this limited supply, by means of an ample extent of land,

to obtain the largest annual produce. Neither at Edinburgh nor at the farm near Barking in the occupation of the Metropolis Sewage Company has the sanitary result or the purity of the water been the object aimed at. In the latter case, however, it has incidentally been secured. The object having been to obtain by agricultural use the largest return from the sewage used, it became necessary to make it as clean as possible before letting it go. At Lodge Farm, near Barking, the Metropolis Sewage Company in 1866 took about 200 acres, for the most part a light gravelly soil, (an analysis of which is given at page 67,) for the purpose of illustrating thereon the value of North London sewage, of which they hold the concession for a term of years. The land had been accordingly laid out in beds varying from 50 to 150 feet in width, with a central carrier down the middle of each, and having a slope from this carrier on either side, down which the sewage trickles to a midway furrow. The carriers are, as nearly as the general slope of the land allows, horizontal; the slope on either side varying from 1 in 20 to 1 in 60. The sewage is pumped from the outfall on the Thames, near Barking, through a 15-inch pipe to a reservoir on the highest part of the farm, and from that it is conducted in open ditches to the ridge-line carriers of these lands. These carriers, being stopped at intervals by the spade of the waterman, overflow; and the sewage, passing over and through the soil to the furrows, is by them conveyed to the lower slopes of the farm, over which it is distributed until it either sinks altogether into the land, or flows finally off the surface at the foot of the farm. The soil is too pervious and has too hollow and open a subsoil to permit the water to travel far upon the surface, so that after 50 yards at most of surface flow it sinks to reappear only at the mouth of the main drain of the farm; which, nearly dry in ordinary weather, pours a full flow within an hour or two of the sewage being applied to the fields. Samples of water taken here represent therefore properly enough the effect of soil and plant upon the London sewage under such circumstances as the Lodge Farm supplies. The following table gives the composition of successive series of samples taken (1) at the carrier, (2) after 50 or 60 yards of surface flow, (3) after a further surface flow; and (*a*) at the foot of the farm where the main drain pours it into a stream.

RAW AND EFFLUENT SEWAGE.—LODGE FARM, BARKING.

RESULTS OF ANALYSIS expressed in Parts per 100,000.

Date and Number of Sample.	Total Solid Matters.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	Suspended Matters.		
							Mineral.	Organic.	Total.
* 1. April 22, 1868	112·50	12·182	3·664	4·000	0	6·958	—	—	—
* 2. " "	90·55	4·331	1·872	2·250	·026	3·751	—	—	—
* 3. " "	91·75	2·768	·624	2·500	·032	2·715	—	—	—
* *a*. " "	79·25	1·366	·329	·800	2·955	3·943	—	—	—
1. June 23rd, 1869	65·30	2·596	1·715	4·000	0	5·009	18·48	27·80	46·28
2. " "	74·30	2·028	1·285	2·437	·693	3·985	3·06	3·40	6·46
a. " "	79·50	·887	·236	·425	2·535	3·121	trace.	trace.	trace.

* In this series of samples the suspended matters were not separated, but the liquids, just as collected, were submitted to analysis.

Comparing 1, 2, 3, with (*a*) in the first, and 1, 2, with (*a*) in the second of these examples, we observe the cleansing effect of land and soil in two separate instances, in both of which about 2,000 tons of sewage passed in the course of nine or ten hours over five or six acres of land; but in neither of them had the sample received more than an hour's treatment from soil and plant together. The soil of the farm is indeed too hollow and porous to allow the most to be made of the manure. Sinking away even in the channels which carry it from the reservoir, much of the sewage is wasted before it reaches the plant; and the remainder which trickles over the surface of the grass remains there too short a time for the entire extraction of the fertilising matter which it conveys.

It will be seen, however, that the effluent waters marked (*a*) in the two series of trials were to a great extent purified.

Turning now to the produce of the sewage, here considered not as a nuisance but as a valuable manure, it appears that 300,430 tons were, in 1867, used over 56 acres of land, and 2,480 tons of Italian ryegrass were cut off that area. Of the sewage, however, no doubt a great deal was lost in the channels and on the land in first starting the process; and, as regards the grass, we are informed that a large proportion was killed by the unusual frost of January 1867, only 13 acres, in fact, of the whole extent having been in full bearing; and these yielded 62 tons of grass per acre. It appears, therefore, upon the whole experience, that for every 100 tons of sewage applied one ton of grass per acre was obtained over and above the natural produce of the soil and climate. In 1868 and 1869, experiments over a considerable extent of land have been made with other crops than grass, to which alone, or to equally succulent growths, so dilute a manure as sewage appears at first sight to be adapted. A field of 13 acres of poor gravel that was in wheat in 1867, yielding then about 3½ quarters per acre, was sown in 1868 in the following manner:—4¾ acres with wheat early in November, 2¼ acres with winter oats, 4 acres with rye, and 2 acres were planted with cabbages in October, which were taken off in March, and mangold sown in their place. The wheat was twice flooded with sewage, in March and in April, 450 to 500 tons to the acre being applied in the two dressings. The crop produced 5½ quarters, and three loads of straw to the acre. The winter oats were three times flooded in March and in April, over the whole, and over a part in June, receiving in all about 500 tons to the acre. These oats yielded eight quarters of corn, with three loads of straw per acre. The rye was flooded twice, in March and in April, in all with about 450 to 500 tons per acre; it was cut in July, and thrashed in the field, yielding six quarters, with three loads of straw.

If it be urged that in such an unusually dry season as 1868, good results would necessarily follow irrigation with town sewage, it must be remembered that although these crops no doubt benefited in common with those of the whole country by the lengthened fine weather, the soil is a dry burning gravel, and no sewage was applied to either wheat or rye after the month of April, up to which time there was the ordinary amount of wet weather, without any unusual heat. The same field has been again in wheat and oats and barley, and the experience of 1869, with a cold May and June, equally with that of the hot and dry season of the previous year, bears ample testimony to the power of sewage upon this soil as a manure for corn crops. The wheat has yielded 4 quarters per acre, the winter oats no less than 11 quarters per acre, the barley

ripening unkindly only 4½ quarters per acre; but it must be remembered in all these cases that the field, naturally a poor gravelly soil, was then yielding its third successive grain crop. Most satisfactory results also continued to be reported last year* from Lodge Farm in the cultivation of potatoes, cabbages, beet, mangold-wurtzel, and other green crops. The Lodge Farm experience, confining it to its growth of grass, may be said to represent a return of 5*s.* annually from every individual contributing to the sewage used upon it. Supposing the water supply to be over 30 gallons a head, each person will make 50 tons of sewage annually, corresponding to the production of 10 cwt. of grass, worth 10*s.* a ton.

The experience here, combined with the tabular statement, page 84, of the analyses of the clear effluent water, pouring from the farm into the neighbouring brook, is sufficiently encouraging for those who are interested in the cleanliness of both town and river.

We turn now to a large number of instances of irrigation, where the object has been not only to make a profit but to abate a nuisance. Such are the cases of Aldershot, Banbury, Bedford, Croydon, Norwood, Rugby, Warwick, and Worthing.

3. *Aldershot Farm.*—The case of Aldershot may be placed first upon the list, because here land has been taken for irrigation, not by the authorities, but by a tenant who, bound no doubt to cleanse the sewage of the camp, yet has for his principal object the extraction of a profit from its use, so that he comes more nearly under the same class with the example last named. Mr. Blackburn here receives the drainage of the North and South Camps, *i.e.*, of a population which is fairly represented by a constant number of 7,000 adults. During winter the drainage of this population, amounting to about 700 tons a day throughout the year, is poured in succession over the several fields of the farm, 80 acres in all, one half being in one and two years old Italian ryegrass, and the other half growing crops of potatoes, mangold-wurtzel, cabbages, &c. During the summer the crops upon the arable half take but little of the drainage of the camp, and it is then poured almost exclusively over the Italian ryegrass land. The soil is the poor sand of the Aldershot waste (consisting of almost pure silica), prepared at considerable expense by levelling and deep grubbing, so as both to provide a uniform slope over which the water may flow evenly, and to remove the ferruginous "pan" which everywhere underlies the soil, and would hinder the even distribution of fertilizing matter downwards. A few deep drains serve to draw off the water which sinks beneath the surface.

The first set of samples A., taken in the afternoon of July 16th, 1869, were, (1) from the reservoir into which the camp drainage flows; (2) from the lower carrier or surface drain of a plot of about an acre in extent, over a width of 50 yards of which it had slowly trickled amidst a growing crop of ryegrass; and (3) from the mouth of a drain the only effluent water from the farm. The sewage was unusually offensive at the time, and the effluent water was apparently clear. The difference of composition indicated by the analyses shows that while the water (1) just poured on land, in its first passage over a surface already richly manured, apparently dissolved and carried with it some of the stuff left by a previous dressing, so that after its 50 yards of passage the sample (2) exhibited in its composition an even larger quantity of filthy matter in solution, yet in the end, and after passing through the land, the organic nitrogen and ammonia as shown in sample (3) had to a large extent disappeared.

* Notes upon the Sewage Cultivation of Lodge Farm, Barking, by the Hon. H. W. Petre.—(Effingham Wilson, Royal Exchange).

RAW AND EFFLUENT SEWAGE.—ALDERSHOT FARM.

RESULTS OF ANALYSIS expressed in Parts per 100,000.

		Solid Matters in Solution.	Organic Carbon.	Organic Nitrogen.	Nitrogen as Nitrites and Nitrates.	Ammonia.	Total Combined Nitrogen.	Chlorine.	Suspended Matters.		
									Mineral.	Organic.	Total.
A.	1. July 16/69	46·6	5·878	2·052	0	9·025	9·484	9·45	6·72	14·28	21·00
	2. „ „	47·4	7·936	3·053	0	8·267	9·861	9·00	1·76	6·84	8·60
	3. „ „	18·6	·665	·132	1·152	·486	1·684	3·55	·68	·66	1·34
B.	1. May 1/68	93·40	16·335	2·694	0	13·054	13·444	—	5·30	17·90	23·20
	2. „ „	39·00	·504	·129	1·312	·622	1·953	—	·38	·02	·40

The set of samples marked B. in the above table were taken on May 1st, 1868. No. 1 was raw sewage, as it passed upon the land, and No. 2 was effluent water from the drain. They indicate an immense reduction in the quantity of all the dissolved polluting materials in sewage by the process of irrigation. The organic carbon was reduced from 16·3 to ·5, and the organic nitrogen from 2·7 to ·1 in 100,000 parts. The above figures show, however, that the whole of this amelioration must not be attributed to the purifying action of the soil and crop, for the solid matters in solution in both series, and the chlorine in series A., point unmistakeably to the admixture of the effluent water with about double its volume of unpolluted spring or subsoil water. All that can be safely inferred from the above analytical results is, that in the series A. the organic impurities, soluble and insoluble, were reduced to less than one-fifth, and in series B. to one-eighteenth, the original sewage in the latter case being much stronger than in the former. Even after this deduction has been made from the observed effect, the result is a very satisfactory one.

In this case the extreme natural poverty of the soil does not seem to have been a hindrance to the efficiency of the process of cleansing by irrigation. The farm, well managed, is covered with a capital plant of vigorous growth, to be fed by the filthy water, which accordingly is greatly purified by the process. Mr. Blackburn lets portions of his land to neighbouring cowkeepers, at 20*l.* an acre; and here the grass, cut in regular rotation, was in the heat of July, when everything was withered and burned up around it, a perfect oasis of luxuriant green, yielding annually its four or five crops of eight to ten tons a piece per acre. The Aldershot farm appears the more satisfactory as an example of the sewage nuisance abated, at the same time that its filthy contents are converted into valuable produce, from the circumstance that a previous attempt to deal with it by subsidence and filtration tanks had been a complete failure.

Supposing 40 acres here to yield 20*l.* an acre, and other 40 acres to owe one-half of their crops, or 10*l.* an acre, to the winter sewaging, we have here a return of 1,200*l.* from the waste of 7,000 adults, or 3*s.* 4*d.* per head per annum.

4. *Carlisle.*—The sewage of Carlisle finds its way, for the most part, into the *Eden* through the main sewer beneath the alluvial pasture land bordering the river. It is delivered in the middle of the river channel through a submerged iron pipe. On the town side of the meadow a pumping station has been erected by Mr. McDougal, to whom the land (about 100 acres) is let; and a quantity is thus

lifted, deodorized by treatment with carbolic acid, and distributed over the land by means of light portable iron troughs. These are shifted from place to place by the man in charge, and in this way the sewage pours on at one place after another, distributing itself with more or less regularity, according to the natural surface of the land, which has not been levelled,—flowing here, ponding there, soaking everywhere. There is an obvious increase in this way to the natural fertility of the land; and a larger quantity of stock is kept upon it than it would naturally maintain. There is no surface drainage from the land to the river, and our sample for analysis was taken by digging a hole three feet deep, close to where the sewage had been lying on the previous day, and taking the water to which we at length came.

RAW AND PURIFIED SEWAGE.—CARLISLE.

RESULTS OF ANALYSIS expressed in Parts per 100,000.

Description.	Total Solid Matters in Solution.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	Chlorine.	Suspended Matters.		
								Mineral.	Organic.	Total.
Raw sewage, Sept. 23, 1868.	44·9	2·673	·505	1·912	0	2·080	—	5·24	4·64	9·88
Water from hole dug in irrigated meadow, Sept. 23, 1868.	28·8	·591	·204	·025	0	·225	3·18	0	0	0

As there is properly speaking no effluent water from this meadow, the whole of the sewage applied being absorbed by the sandy soil and there being no drain outlet, the result is not quite so trustworthy as in other cases; nevertheless we may fairly conclude from it that the soakage from the irrigated land into the neighbouring river is effectually purified.

5. *Penrith.*—Here the drainage of a town of 8,000 people, only partly provided with waterclosets, is received on 80 acres of good meadow land near the *Eamont*. A little more has been done here than at Carlisle to distribute the water by means of permanent carriers; but the treatment is otherwise the same, and the result is very similar. A very large stock of cattle and sheep is kept upon the land to graze down the abundant growth of grass which is obtained.

RAW AND EFFLUENT SEWAGE.—PENRITH.

RESULTS OF ANALYSIS expressed in Parts per 100,000.

Description.	Total Solid Matters in Solution.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total combined Nitrogen.	Chlorine.	Suspended Matters.		
								Mineral.	Organic.	Total.
Raw sewage, Sept. 24, 1868.	53·5	5·111	1·899	10·395	0	10·460	—	5·88	11·88	17·76
Effluent water from drain as it enters the Eamont, Sept. 24, 1868.	21·9	·320	·108	·001	0	·109	2·68	0	0	0

Here, as at Carlisle, the whole of the sewage is absorbed into a porous sandy soil, but the drain passing beneath the irrigated land, and alluded to in the table, pours out a considerable and clear stream into the *Eamont*, and from this the sample of effluent water whose analysis is given was taken. The comparatively small proportions of solid matters in solution, and especially of chlorine in the effluent water, point to the admixture of unpolluted subsoil water with the true effluent sewage, and the figures in the above table indicate that no less than three volumes of this pure subsoil water mingled with one volume of the real effluent sewage. But even after making this deduction from the purifying effect of the irrigation the result is still satisfactory. The whole of the suspended impurity was removed whilst a reduction of the organic matter in solution was effected to the extent of 75 per cent. of organic carbon and 77·2 per cent. of organic nitrogen.

6. *Rugby.*—At Rugby, a town of more than 8,000 inhabitants, the Board of Health have taken a lease of 65 acres of land for a term of 31 years, at a rental which, with rates and taxes, amounts to 4*l.* 10*s.* per acre ; and, confident in the powers of their somewhat gravelly soil (lying upon a clay subsoil) to cleanse their town drainage, and to convert it into valuable produce, they have laid out nearly 5,000*l.* on the works required for the distribution of the sewage water over it. An intercepting sewer takes the drainage of all the upper part of the town by natural gravitation to the top of the farm ; and, by a deep and costly tunnel drain, the waste of all the lower part of the town is made to flow (along with the tail water of the upper fields) over about 16 acres of the lower part of the farm.

The quantity of sewage at command is about 900 tons a day, or nearly 4,000 tons per annum for every acre of the farm. The land has been in hand for only one year, and much of it was sown with Italian ryegrass for the first time in the spring of 1869, so that the best results can hardly have been yet realized. The third and fourth cuttings (both heavy crops) were, however, ready in the following month of July, and a sale was being obtained for the grass at 8*s.* a ton upon the land. A considerable portion had been let at 10*l.* an acre ; and the 16 acres at the lower end of the farm had supported throughout the spring and summer 54 head of cattle, consuming at least four tons of its grass produce daily ; and a considerable extent of the crop on these 16 acres had been made into hay. In illustration of the cleansing power of land and plant at Rugby, three samples taken about mid-day, July 13, have been analysed ; No. 1 was raw sewage taken from the hydrant as it poured over the top of the farm ; No. 2 was the same sewage taken at the foot of 1½ acre of land in Italian ryegrass over which it had passed 150 yards down the slope. Thence it flowed along a surface channel about 300 yards to another acre of Italian ryegrass ; and No. 3 was taken at the foot of this grass plot about 80 yards from the carrier which supplied it. The following table gives the results :—

RAW AND EFFLUENT SEWAGE.—RUGBY.

RESULTS OF ANALYSIS expressed in Parts per 100,000.

Rugby Samples.	Solid Matters in Solution.	Organic Carbon.	Organic Nitrogen.	Nitrogen in Nitrites and Nitrates.	Ammonia.	Total Combined Nitrogen.	Chlorine.	Suspended Matters.		
								Mineral	Organic.	Total.
1. July 13/69 -	52·60	5·505	2·322	·000	7·276	8·314	8·25	3·48	8·96	12·44
2. „ „ -	55·70	2·547	·506	·000	2·772	2·789	10·20	·72	·28	1·00
3. „ „ -	68·20	1·526	·164	·000	·420	·510	10·50	·88	·36	1·24

Here then is a case in which the nuisance of the sewage is entirely abated, and so much produce realized as to make it probable that the remedy, which has been here an expensive one, will yet prove profitable,

The following account of the experience of 1869 at this place has been communicated to us by Mr. T. M. Wratislaw, Clerk of the Local Board of Health :—

"The gross produce of the sewage-farm, for the year ending 31st December, has been 544*l.* 16*s.* 8*d.* The total expenses, so far as the payments (including wages for the year) have been made, stand at 458*l.* 8*s.* 5*d.*, and I do not apprehend much addition."

"I am not aware of the actual number of persons contributing to the sewage utilized, but should estimate 7,800."

7. *Banbury.*—A population of about 11,000 people here drain into tanks, from which, through a 12-inch pipe, the sewage is driven by steam power a mile or more to the upper end of a farm of 136 acres, a lease of which has been taken for 21 years, at a rent of 4*l.* 10*s.* per acre. The quantity thus applied amounts to about 300,000 gallons a day, or about 4,000 tons per acre per annum over that part of the farm which is under irrigation. The sewage settles to some extent in the tanks from which the pumps lift it, and both mud and scum are here taken from it, and mixed with the street sweepings and other scavenging refuse of the town ; and 2,000 tons of this compost were sold last year, for which a sum of about 100*l.* was received at the depôt, the material being loaded by the purchaser into barges on the canal close by. The liquid part, delivered on the highest part of the farm, having about 17 feet of fall before it reaches the river *Cherwell*, flows twice or thrice over successive fields before it is finally dismissed, and the extreme filthiness of the river formerly complained of is now satisfactorily abated.

The following samples illustrate the cleansing process which the sewage thus undergoes. The series A. was taken at our visit to Banbury on October 17th, 1868; No. 1 being the sewage which had accumulated in the pumping well from 10 a.m. to 2 p.m., and No. 2 the effluent water as it left the meadows at 1 p.m. The series B. was collected on July 14th, 1869. No. 1 was taken at 10 a.m. and at noon, being raw sewage taken partly from the upper carrier on the farm and partly from the pump well. No. 2 was the water after it had passed over 200 yards in length, and four acres in extent of a field of Italian rye-grass, at the rate of, probably, 70 tons an hour. No. 3 was taken after this tail water had travelled half a mile in an open carrier, and then distributed itself over a flat meadow of permanent grass land. It was passing from the underground drain of the field in question, and represents the sewage as it reached the river. The farm is for the most part a very stiff soil, and the greater part of it is still in old grass land, and neither circumstance is favourable to its efficiency; the former because the soil tends to crack in dry weather, thus given the sewage direct access to underground drains, and thence to the river before it has been properly acted upon by the soil ; and the latter because the surface of the land not being specially and evenly laid out for irrigation, the water tends to collect in shallow ponds or puddles, to the injury of the produce, without being itself materially cleansed. The accounts given of the produce of the land are satisfactory, and it is believed that the farm will soon repay rent, and costs, and loan, so that the nuisance hitherto created by the town will be ultimately abated without any serious permanent charge upon the inhabitants.

The produce of Italian ryegrass and of the meadow land is sold by auction as the successive cuttings are ready for the scythe; and prices varying from 3*l.* to 5*l.* an acre have been obtained per cutting. The following are the results of our analyses:—

RAW AND EFFLUENT SEWAGE.—BANBURY.

RESULTS OF ANALYSIS expressed in Parts per 100,000.

Banbury Samples.		Total Solid Matters in Solution.	Organic Carbon.	Organic Nitrogen.	Nitrogen in Nitrites and Nitrates.	Ammonia.	Total Combined Nitrogen.	Chlorine.	Suspended Matters.		
									Mineral.	Organic.	Total.
A.	1. Oct. 17 68	111·5	6·246	2·764	·000	13·590	13·956	—	3·90	8·62	12·52
	2. „ „	70·9	2·241	·549	·000	2·282	2·428	13·25	·52	·84	1·36
B.	1. July 14/69	92·4	8·269	2·386	·000	6·702	7·905	8·75	9·56	20·12	29·68
	2. „ „	66·5	2·670	1·127	·000	3·112	3·690	6·75	1·68	3·84	5·52
	3. „ „	51·8	1·008	·207	·668	·725	1·472	5·50	·94	·80	1·74

The Banbury sewage, owing to a deficient water supply, is sometimes much above the average strength, and consequently its efficient cleansing is then a more difficult operation; nevertheless the above results are by no means unsatisfactory; and they are improving, both as regards the cleanness of the effluent water and the returns from the use of it.

The following account of receipts and expenses, in respect of the sewage-farm here, for the year ending Lady-day 1869, has been supplied to us by Mr. T. Pain, the town clerk:—

Receipts.

	£	*s.*	*d.*
Amount realised from sale of ryegrass	561	16	6
„ „ mowing grass	347	18	2
„ „ oats	198	0	0
„ „ aftermath	166	11	8
Right of shooting over farm, and sundries	6	1	6
	1,280	7	10

Payments.

	£	*s.*	*d.*			
Mr. Tomline, a year's rent less property tax	605	3	1			
Rates and taxes for the year	57	4	7			
Coals for engine	111	16	0			
Labour expended in cultivation of farm	216	2	0			
Seeds, implements, &c.	82	0	6			
Manager's salary	45	0	0			
Auctioneer's expenses of sale, including commission	73	6	11			
				1,190	13	1
Profit on farm				89	14	9
Instalment of principal and interest in respect of loan of 4,000*l.* borrowed to carry out the irrigation work				250	0	0

The produce of the summer of 1869, when we were over the farm, bid fair to at least maintain the satisfactory character of the account on the previous page.

8. *Warwick*, a town of 11,000 inhabitants, occupying 2,400 houses, of which upwards of 2,000 are connected with the sewers, has lately poured its sewage over a clay-land farm of 100 acres, about a mile away. The quantity thus pumped, and which formerly fouled the *Avon*, amounts to about 600,000 gallons a day, double the water supply of the town, or nearly 1,000,000 tons a year, corresponding to 10,000 tons per acre annually. A large quantity of very dilute drainage water thus flows over a very stiff and therefore less appropriate soil. What the result is, as regards its cleansing powers, appears from the following analyses:—No. 1 is a sample of raw sewage taken from the receiving tank by the pump at 4 p.m. on July 14th, 1869. No. 2 is the sewage after flowing over seven acres of recently-cut Italian ryegrass taken at the foot of a field of red clay soil down which it had flowed probably 200 yards at the rate of 80 or 100 tons an hour. No. 3 is the same water after a second cleansing over three acres of Italian ryegrass in a field of similar soil. The results here may be taken to represent the powers of plant growth and of mere surface action of clay soil, for none of the water apparently had sunk into the land or been absorbed. Here the filth in about 150 tons of dilute sewage had been satisfactorily reduced by probably two hours' irrigation treatment, under what must be pronounced unfavourable circumstances. Moreover the sewage, and consequently the residual impurities had obviously undergone concentration by evaporation, as is seen from the continuous increase of chlorine in the successive samples.

RAW AND EFFLUENT SEWAGE.—WARWICK.

RESULTS OF ANALYSIS expressed in Parts per 100,000.

	Total Solid Matters in Solution.	Organic Carbon.	Organic Nitrogen.	Nitrogen as Nitrites and Nitrates.	Ammonia.	Total Combined Nitrogen.	Chlorine.	Suspended Matters.		
								Mineral.	Organic.	Total.
1. July 14/69 - -	66·90	5·133	1·680	·000	2·439	3·689	6·30	2·64	3·36	6·00
2. „ - -	69·70	2·727	·575	·000	1·705	1·979	7·70	3·30	·78	4·08
3. „ - -	66·10	1·454	·175	·137	·839	1·003	8·15	Trace.	Trace.	Trace.

The farm has been in hand for two years. Pumping commenced only in the autumn of 1868, and it was not continously carried on until the following year. This, together with the difficulty which the low and flat part of the farm presents to the proper drainage from it of so large a quantity of water, has hitherto delayed the satisfactory financial result which is looked for. Nevertheless the nuisance is sufficiently abated, and large crops of Italian ryegrass have been obtained, for which a ready sale at 10*s.* and 12*s.* a ton upon the ground has latterly been obtained. The farm must, we understand, pay at least 1,600*l.* a year to replace the costs which the town has already incurred and still bears in respect of rent, pumping, and works

9. *Worthing*, containing about 8,000 inhabitants, has hitherto fouled a stream running into the sea two miles to the eastward of it. The town drainage now runs to a tank from which it may flow as heretofore, and still does run during the night, so that a good deal of very offensive filth even now lodges in the bed of the stream. During the day it is pumped and flows upon the land of the Worthing Land Improvement Company, who have about 100 acres on which to receive it. The soil is a good free loam perfectly well adapted for their purpose, and the natural slopes are quite sufficient for the easy distribution of the water. There are on the lower part of the farm upwards of 40 acres of an alluvial flat of natural grass on which the effluent drainage of the higher arable land received before it leaves the farm. Mr. W. Hugh Dennett, solicitor to the Worthing Land Improvement Company, has communicated to us the following account of the gross receipts and working expenses of the sewage-farm for the year 1869 :—

	£	*s.*	*d.*
" Receipts - - -	1,807	4	9
" Expenses - - -	1,045	6	9
" Balance - -	761	18	0

" In the above expenditure is included a sum of 51*l.* 13*s.* 11*d.* for a 'Level' rate, made for the protection of various lands from the encroachments of the sea, which is a special and not an ordinary parochial rate. There is also included a sum of 50*l.* for the rent of 8½ acres of the land referred to and comprised in the area stated below. A steam engine on the farm was used for about three months at a cost of about 25*l.*

" The population of Worthing is about 7,600.

" The engineer reports that the average volume of sewage pumped each day of 24 hours to the farm is about 480,000 gallons (of which about 130,000 gallons are spring or surface water). In addition to this, about 80,000 gallons of water per day flow into the *Treville* stream.

" The extent over which the sewage flows is about 83 acres.

" The whole farm consists of about 96 acres, a portion of which is not sewaged ; 42 acres are pasture land.

" I cannot say that the pollution has altogether ceased, because although it is stated that the 80,000 gallons of sewage flowing into the stream per day is top water, yet it flows from the sewage-well, and must be necessarily polluted with sewage. However, the actual pumping of the sewage into the stream ceased some months ago, and the communication has been removed. The Local Board of Health have also cleansed the stream, and there is reason to believe that all the sewage pumped goes upon the land, though materially diluted by spring and surface water."

Our samples of the Worthing sewage were taken on July 15th, 1869, about 3 p.m., (1) from the head carrier, (2) from a carrier 150 yards lower down at the foot of a field of Italian ryegrass, over three or four acres of which the sewage was passing at about the rate of 60 tons an hour, and (3) from the effluent stream at the foot of the farm after it had further spread over two or three acres of the flat alluvial grass plot by the river. The following results were obtained on analysis :—

RAW AND EFFLUENT SEWAGE.—WORTHING.

RESULTS OF ANALYSIS expressed in Parts per 100,000.

—	Total Solid Matters in Solution.	Organic Carbon.	Organic Nitrogen.	Nitrogen in Nitrites and Nitrates.	Ammonia.	Total Combined Nitrogen.	Chlorine.	Suspended Matters.		
								Mineral.	Organic.	Total.
1. July 15/69 -	57·6	2·312	2·021	·000	3·717	5·082	10·75	1·86	4·74	6·60
2. „ „ -	58·8	1·164	·226	1·105	·801	1·991	11·40	Trace.	Trace.	Trace.
3. „ „ -	59·8	1·324	·334	·248	·591	1·069	11·00	„	„	„

The sewage, which was somewhat weak at the time of our visit, was sufficiently cleansed by passing over the first plot; indeed it was cleaner than another sample from the effluent stream which was probably carrying into the river the purified water from the stronger morning sewage. Close proximity to the sea affects the proportion of common salt in the Worthing sewage. The proportion of chlorine in all the samples is much higher than the strength of the sewage would lead us to anticipate. Some of the streets are watered with sea water.

10. *Bedford.*—At Bedford, which contains about 15,000 inhabitants, large sums have been recently laid out under the direction of Mr. John Lawson, C.E., on both its water supply and its drainage system. The sewers here receive not only the fouled water-supply of the town, together with a certain proportion of the rainfall on its houses and yards, but an immense quantity of land-water from the gravel site on which the town is built. Thus, though the water-supply does not much exceed 150,000 gallons daily, the quantity of drainage which reaches the pumping station, about a mile below the town, is as much as 500,000 or 600,000 gallons daily. Each of the two 12-horse power engines here stationed is, however, capable of lifting 2,000 gallons a minute to a height of 20 feet, so that either of them can master the ordinary dry-weather sewage of the place.

During the night the comparatively pure water which then drains away is stored in the outfall sewer and tank at the pumping station. In the daytime it is delivered by an 18-inch iron pipe to the irrigated land 400 or 500 yards off, flowing thence into a small circular tank, and afterwards by two 15-inch pipes, along either side of the nearly flat land which has been laid out in transverse beds for its reception. These beds are about 70 feet wide on the side, with a fall of 8 or 10 inches from the central carrier to the midway furrow. The carriers are either 5-inch pipe tiles with open longitudinal slit, or 8-inch half round tiles; and a fall of about 1 in from 300 to 800 is given to them.

The beds were sown in 1868 with Italian ryegrass, and have yielded heavy crops. Up to the middle of July three crops had been cut off 20 acres, besides one crop off 15 acres sown in 1869, and the sales amounted to nearly 330*l.* A much larger area of land is about to be taken in hand for irrigation purposes by the Corporation. The extent at present rented is about 50 acres, but a farm of about 200 acres will ultimately be under their management. The cost of pumping, which amounts to 4*l.* per acre of the land now irrigated, will then be reduced

to a rentcharge of about 20*s.* an acre, which will be more easily repaid. And as the houses become more generally connected with the sewers, both the need of the greater area, and the produce derived from so large a supply of fertilizing matter, will increase. At present, as the following analyses show, the sewage is very weak, but the cleansing process is satisfactory. The samples of raw sewage (1, in the following table) were taken from the above mentioned tank upon the farm; the effluent water (2) was taken from a ditch, which is dry except when the sewage is pouring on the land, but which was then flowing rapidly, being supplied from the subsoil drainage of the field which was being irrigated.

Samples were taken by us on three occasions. Series A. was collected on Sept. 10th, 1868, series B. on Oct. 10th, 1868, and series C. on July 24th, 1869.

RAW AND EFFLUENT SEWAGE.—BEDFORD.

RESULTS OF ANALYSIS expressed in Parts per 100,000.

Times of Collection.	Total Solid Matters in Solution.	Organic Carbon.	Organic Nitrogen.	Nitrogen in Nitrites and Nitrates.	Ammonia.	Total Combined Nitrogen.	Chlorine.	Suspended Matters.		
								Mineral.	Organic.	Total.
A. 1., 4.45 P.M.	74·8	2·732	·668	·000	2·700	2·891	—	13·26	13·14	26·40
A. 2., 5.0 „	76·8	·575	·163	·398	·023	·580	7·15	0	0	0
B. 1., 12.30 P.M.	79·4	1·877	1·304	·000	4·300	4·845	—	5·58	5·50	11·08
B. 2., 1.30 „	78·3	·742	·381	·600	·010	·989	7·25	0	0	0
C. 1., 4.50 P.M.	76·1	2·256	1·301	·000	3·100	3·854	10·90	8·16	13·68	21·84
C. 2., 5.30 „	81·7	·558	·034	·505	·095	·617	8·17	0	0	0

The undertaking here is thus shown to be sufficient as a sanitary agency, and its ultimate profitableness appears probable from the character of the crops we saw growing on the land. The Italian rye-grass must have weighed 12 to 14 tons per acre. The mangold-wurtzel and kohl-rabi were tolerably promising. The prices obtained by auction for the former crop were improving at the successive sales, as the prejudice against sewage-grown cattle food was dying out. The difficulties connected with the even distribution of the liquid will also diminish every year as the settlement of the moved land enables the necessary corrections of the surface to be made, so as to ensure a more uniform flow of water over it. The following report for 1869 has been furnished by Mr. John Lawson, C.E.:—

"The land leased by the Corporation from the Duke of Bedford contains 54a. 3r. 7p. Of this area 47 acres have been irrigated by sewage.

"Two fields, containing about 22 acres, were sown with Italian rye-grass in 1868, and the produce sold from this land in the year 1869 was about 420*l.*

Of the remaining portion of the land irrigated 15a. 2r. were sown with Italian ryegrass in the spring of 1869, and the remainder with mangold-wurtzel and other root crops. The sales from this portion amount to about 227*l.* 10*s.* 4*d.*, making a total of 647*l.* 10*s.* 4*d.*

	£	s.	d.
" Produce in the year 1869 as sold by auction -	647	10	4

	£	s.	d.	£	s.	d.
Rent, 55 acres at 4*l.* 10*s.* - -	247	10	0			
Auctioneers commission - -	33	8	6			
Printing - - - -	22	9	0			
Seeds and plants - - -	33	19	0			
Labour, including salary of manager	213	4	0			
Taxes - - - -	17	14	8			
Sundry expenses - - -	11	19	0			
				580	4	2
				£67	6	2"

11. *Norwood.* The history of the facts connected with sewage irrigation at Norwood and at Croydon has been sufficiently prolonged to make it now thoroughly trustworthy and instructive. At the former place about 30 acres of low-lying clay land, with sufficient slope for natural surface drainage, have been well laid out for irrigation by Mr. Baldwin Latham, C.E. The drainage of about 4,000 people is received into a subsidence tank at the upper end, and thence flows along surface carriers, arranged both nearly in contour and down the slope. The fall in these carriers varies from 1 in 100 to 1 in 1,000, and the water stopped at intervals in their course flows over their edges, and so finds its way over the surface of the land. Plots varying in size from one to three acres are irrigated at once, according to the abundance of the supply, which, especially in summer time, when it is most wanted, is barely sufficient for the proper irrigation of the land. Nevertheless, very good crops of Italian ryegrass are cut five or six times a year; and a ready sale is obtained for the produce, at prices varying from 9*d.* to 1*s.* 3*d.* per rod, or 6*l.* to 10*l.* per acre, and the Croydon Board of Health have in this way obtained a revenue of 22*l.* per acre during nine months of 1868, and 25*l.* per acre in 1869, which spread over the population to whose drainage it is due, amounts to about 3*s.* 9*d.* per head per annum. Mr. Baldwin Latham has furnished the following satisfactory report of the past year's experience :—

	£	s.	d.
" The total amount received for the produce in the year was - - - - -	741	0	6

The expenditure has been as follows :—

	£	s.	d.	£	s.	d.
Rent after deducting income tax -	292	16	3			
Wages for cutting produce, attending to the distribution of the sewage, re-digging and otherwise preparing the land for crops -	196	1	3			
Seed - - - -	17	2	6			
Taxes, rates, and tithes - -	63	15	3			
Printing - - - -	2	3	0			
Sundry bills - - -	20	16	6			
				592	14	9
Balance - -				£148	5	9

"The area under irrigation is 30 acres. Previous to the Local Board becoming the tenants of the land, the rent paid was 18*s.* per acre. The adjoining agricultural land is let at less than 1*l.* per acre rent. The average population draining to this area during the last year has been about 4,000. During the last month or two we have made provision to bring in a much larger area to this outfall, and in order to make provision for the increased population the Board has taken a sufficient area of land adjoining the present irrigation works at a rent of 10*l.* per acre. This will nearly double the existing area under sewage. It may also be interesting to the Commissioners to know that when the existing works at South Norwood were completed they were let to a tenant for three years, at a rent of 200*l.* per annum. The Board at this time paid the cost of distributing the sewage, so that as long as the works were let, there was a clear loss to the Board of 180*l.* per annum, but since they have taken them into their own hands a profit has accrued as will be seen from the foregoing figures."

A series of samples of raw sewage and effluent water has been taken from this land, giving the following results:—

RAW AND EFFLUENT SEWAGE.—NORWOOD.

RESULTS of ANALYSIS expressed in Parts per 100,000.

Date of Sample.		Total solid Matter in Solution.	Organic Carbon.	Organic Nitrogen.	Nitrogen in Nitrites and Nitrates.	Ammonia.	Total Combined Nitrogen.	Chlorine.	Suspended Matters.		
									Mineral.	Organic.	Total.
February 25, 1869	Head	91·70	3·235	·699	·000	2·030	2·371	8·60	3·68	6·36	10·04
	Tail	73·20	1·577	·391	·423	·988	1·628	5·70	Trace.	Trace.	Trace.
March 12, 1869	Head	117·80	5·407	2·294	·000	8·970	9·681	8·87	4·08	14·96	19·04
	Tail	83·10	1·294	·184	·381	·965	1·360	8·87	Trace.	Trace.	Trace.
March 25, 1869	Head	75·30	3·275	1·765	·000	7·097	7·610	8·50	5·88	8·36	14·24
	Tail	97·80	1·061	·189	·462	·342	·933	7·50	Trace.	Trace.	Trace.

The relative cleansing which sewage undergoes by employment for irrigation at different seasons of the year has not yet received any sufficient elucidation. The proximity of Norwood and Croydon to London afforded a favourable opportunity of submitting the effluent water from the two sewage-farms to frequent investigation at all seasons of the year. Arrangements were, therefore, made for the periodical collection of samples for an entire year by our own laboratory man, in order to ascertain how far the efficient cleansing of sewage by this method is affected by the vigour or otherwise of vegetation, and especially whether the process could be relied upon during the winter months when plant life is in a comparatively dormant condition.

The following table contains the results of our periodical analysis of the effluent water from the sewage-farm at Norwood:—

EFFLUENT WATER.—IRRIGATED MEADOWS, NORWOOD.

RESULTS of ANALYSIS expressed in Parts per 100,000.

Description and Date of Collection.	Total solid Matters in Solution.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Combined Nitrogen.	Chlorine.	Hardness.		
								Temporary.	Permanent.	Total.
Average composition of the sewage before irrigation	**94·9**	**3·972**	**1·586**	**6·032**	**·000**	**6·554**	**8·66**	—	—	—
Effluent water, September 24, 1868	81·7	1·621	·214	·013	·843	1·068	9·73	18·64	14·26	32·90
,, October 8, ,,	95·3	1·516	·189	·006	·587	·781	9·93	15·84	22·14	37·98
,, ,, 22, ,,	88·4	1·372	—	1·080	·710	—	9·93	17·68	16·70	34·38
,, November 19, ,,	78·0	1·473	·285	1·366	·167	1·577	9·73	11·80	22·90	34·70
,, December 3, ,,	79·6	1·258	·323	1·052	·694	1·883	8·54	4·18	27·74	31·92
,, ,, 17, ,,	103·0	1·187	·120	1·254	·796	1·948	8·74	8·18	30·45	38·63
,, ,, 31, ,,	77·8	1·291	·098	·497	1·450	1·957	6·75	9·30	25·56	34·86
,, January 14, 1869	86·5	1·221	—	·721	·287	—	7·84	15·97	21·35	37·32
,, ,, 21, ,, after two nights' frost	94·3	1·173	·265	·720	·088	·946	8·44	19·31	18·99	38·30
,, ,, 25, ,, after seven nights' frost	100·3	1·431	·419	1·095	·072	1·393	10·13	24·23	16·37	40·60
,, ,, 28, ,,	77·3	1·280	·406	1·195	·240	1·630	7·55	18·99	17·02	36·01
,, February 11, ,,	83·8	1·130	·133	·300	·549	·929	6.80	20·30.	19·97	40·27
,, ,, 25, ,,	73·2	1·577	·391	·988	·423	1·628	5·70	16·86	17·19	34·05
,, March 12, ,,	83·1	1·294	·107	·965	·381	1·283	—	—	—	46·95
,, ,, 25, ,,	97·8	1·061	·189	·342	·462	·933	7·50	16·54	20·93	37·47
,, April 8, ,,	81·6	1·376	·321	·885	·547	1·596	8·00	19·68	17·16	36·84
,, ,, 22, ,,	102·5	1·495	·260	·842	·081	1·034	8·80	19·32	20·34	39·66
,, May 6, ,,	84·3	1·483	·410	1·131	·026	1·367	7·75	15·36	22·11	37·47
,, ,, 20, ,,	83·0	1·602	·354	·730	·498	1·453	7·50	14·03	19·67	33·70
,, June 3, ,,	97·1	1·683	·250	·415	·167	·759	9·64	17·80	20·92	38·72
,, ,, 17, ,,	79·8	1·360	·221	·894	·000	·957	8·50	17·95	16·69	34·64
,, July 1, ,,	95·1	1·577	·271	·905	·950	1·966	10·50	24·23	16·06	40·29
,, ,, 15, ,,	94·0	2·160	·274	·408	·705	1·315	13·10	23·63	11·95	35·58
,, ,, 29, ,,	93·6	1·889	·210	·135	·354	·675	10·20	20·77	17·01	37·78
,, August 12, ,,	93·8	2·095	·339	·130	·608	1·054	11·80	20·91	14·36	35·27
,, ,, 26, ,,	74·3	1·605	·370	·673	·000	·924	11·40	17·27	18·63	35·90
,, September 9, ,,	89·2	2·085	·300	·300	·403	·950	10·90	19·91	16·93	36·84
,, ,, 24, ,,	87·0	2·034	·517	1·128	1·390	2·836	10·60	17·50	16·37	33·87

These results, extending over an entire year, show that the effluent sewage was, except in a few instances, so far cleansed, even upon this heavy clay soil, as to be admissible into running water without nuisance. Two of these instances are instructive, since they occurred consecutively during and immediately after seven nights' frost, viz., in the samples collected on January 25th and January 28th, 1869. The frost was by no means severe, yet the organic nitrogen rose from ·098 to ·419 per 100,000 parts of effluent water, showing that the removal of offensive nitrogenous organic matter was partially arrested, and indicating that during a severe winter the purification of sewage upon a non-absorptive clay soil may be seriously interfered with. It is fortunate, however, that the admission of putrescible organic matter into streams during frosty weather is far less objectionable than it is when the temperature is higher, since the organic matter does not render the water offensive so long as a low temperature is maintained.

It is more difficult to account for the emission of exceptionally impure water from the Norwood Farm at other periods of the year, viz., on December 3rd, 1868, and February 25th, April 8th, May 6th and 20th, August 12th and 26th, and September 24th, 1869, but it probably arose, in some cases at least, from unpurified sewage gaining access to the drains through cracks in the soil.

The hardness of the effluent water was not excessive, although it exceeded considerably that of the water supplied to Norwood. It never contained more than traces of suspended matters.

12. *Croydon*.—At the Beddington meadows below Croydon, 260 acres of an open soil upon a gravelly subsoil have for the last seven years received the drainage water of from 30,000 to 40,000 people. The water-supply of Croydon and the copious land drainage of the place altogether yield a quantity of sewage equal to at least 3,000,000, sometimes exceeding 5,000,000 gallons daily. This passes through tanks where great pains were formerly taken to remove the solid and floating filth which it carried down, but less attention is now paid to this preliminary process, and the stream flows on very nearly as it leaves the town to the meadows in the occupation of Mr. Marriage, who, paying the rent at which the Board of Health have hired or bought the land, pays also a profit rent of 1*l.* per acre per annum for the use of the sewage. The success of sewage irrigation here as a deodorizing and cleansing process is complete, as the analyses show. There is never any lack of water, the soil is open, and has just slope enough to render easy the distribution of the liquid over it and through it, and there is sufficient fall between the top and bottom of the farm to allow the tail water of the upper fields to be spread a second time over fields below before it drains finally away. Very heavy crops of Italian rye-grass have been grown here. As much as 14 to 16 tons per acre are cut early in the month of May, and four or five cuttings a year are obtained, averaging from 8 to 10 tons each per acre. Mr. Marriage has also successfully used dressings of sewage in the cultivation of mangold wurzel; and when wheat has been grown after sewaged grass, he has irrigated the field with advantage, even so late as the month of July, when the crop has appeared to be flagging and apparently suffering during a drought. Watercresses too have proved here an excellent crop for sewaging, not only from the profit derived from them, but from their cleansing powers upon the dirty liquid. The greater part of the land here irrigated is, however, in grass. That being the only crop which can be continuously watered with advantage, it is necessary to retain the greater part of the farm in grass in order that the enormous

quantity of dirty water here passing over the land may be changed from field to field often enough, and cleansed sufficiently before it leaves the land. Latterly, much of the land has been laid down to permanent grasses, which are better adapted for ordinary grazing purposes, and a large herd of feeding cattle have been successfully grazed upon these lands; being moved from field to field as the water drains off them. This was, however, we presume, a temporary arrangement intended to diminish the tenant's costs as the expiry of his lease approaches, and not intended as an example of the best method of converting the fertilizing matter of sewage into valuable produce.

The following results of analysis illustrate the effect of irrigation when carried out upon the porous gravelly soil of the Beddington meadows. It will seen that the sewage as it flows upon the land possesses scarcely half the strength of average London sewage. The effluent water, even in the month of December, was satisfactorily cleansed and contained but mere traces of suspended matters.

Raw and Effluent Sewage.—Croydon.

Results of Analysis expressed in Parts per 100,000.

Description.	Total Solid Matters in Solution.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrites and Nitrites.	Total Combined Nitrogen.	Chlorine.	Suspended Matters.		
								Mineral.	Organic.	Total.
Sewage as it flowed upon land, Dec. 28, 1869.	48·0	2·076	·749	2·684	0	2·959	4·39	1·96	6·64	8·60
Effluent water, Dec. 28, 1869	52·3	·795	·072	·265	1·164	1·454	3·70	Trace.	Trace.	Trace.
Sewage as it flowed upon land, Dec. 30, 1869.	48·0	2·882	1·269	2·700	0	3·493	4·30	3·80	10·80	14·60
Effluent water, Dec. 30, 1869	45·0	·772	·076	·530	·678	1·190	2·95	Trace.	Trace.	Trace.

The following table contains the results of our periodical analyses of the effluent water from these meadows, extending over an entire year:—

RESULTS OF ANALYSIS expressed in Parts per 100,000.

Description and Date of Collection.	Total Solid Matter in Solution.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	Chlorine.	Hardness.		
								Temporary.	Permanent.	Total.
Average composition of the sewage before irrigation	**45·7**	**2·508**	**1·576**	**3·005**	**·000**	**3·527**	**3·23**	—	—	—
Effluent water, September, 24, 1868	37·8	·723	·119	·006	·115	·239	2·73	21·03	5·93	26·96
„ October 8, „	37·9	·605	·120	·005	·382	·506	2·58	21·06	6·52	27·58
„ „ 22, „	49·0	·644	·069	·008	·353	·429	3·18	19·10	7·70	26·80
„ November 5, „	39·9	·801	—	·248	·651	—	2·98	20·05	7·69	27·74
„ December 3, „	40·2	·766	·239	·534	·289	·968	3·77	22·57	7·55	30·12
„ „ 31, „	48·7	·632	·124	·130	1·271	1·502	3·47	17·50	14·42	31·92
„ January 14, „	44·7	·604	·186	·166	·941	1·264	3·08	20·82	11·92	32·74
„ „ 21, „ after two nights' frost	46·0	·620	·242	·466	·210	·836	3·18	21·13	9·32	30·45
„ „ 25, 1869, after seven nights' frost	45·1	·562	·235	·275	·686	1·147	2·58	18·50	10·67	29·17
„ „ 28, „	34·5	·614	·093	·165	·425	·654	2·88	21·96	7·84	29·80
„ February 11, „	38·4	·979	·138	·125	·091	·332	2·70	20·24	10·21	30·45
„ „ 25, „	39·9	·541	·089	·098	·776	·946	2·60	13·58	17·19	30·77
„ March 12, „	37·3	·545	·097	·246	·538	·838	2·30	—	—	27·58
„ „ 25, „	38·8	·427	·077	·090	·596	·747	2·40	19·64	8·47	28·11
„ April 8, „	36·2	·637	·122	·150	·396	·642	2·50	19·61	7·90	27·51
„ „ 22, „	39·1	·702	·129	·124	·241	·472	2·24	20·42	6·49	26·91
„ May 6, „	37·1	·758	·083	·032	·245	·354	2·45	21·98	4·93	26·91
„ „ 20, „	37·1	·644	·080	·020	·284	·380	2·15	21·04	6·77	27·81
„ June 3, „	33·9	·531	·127	·062	·183	·361	2·40	18·40	7·90	26·30
„ „ 17, „	29·1	·291	·082	·042	·000	·117	2·18	18·54	7·76	26·30
„ July 1, „	32·1	·761	·036	·050	·301	·378	2·28	20·05	5·36	25·41
„ „ 15, „	38·1	·605	·124	·008	·201	·332	2·60	21·08	4·93	26·01
„ „ 29, „	36·9	·628	·077	·090	·000	·151	2·60	20·93	7·48	28·41
„ August 12, „	39·1	.582	·385	·278	·325	·939	2·60	20·14	6·77	26·91
„ „ 26, „	30·8	·362	·054	·018	·000	·069	2·80	17·89	6·92	24·81
„ September 9, „	32·7	·591	·105	·038	·147	·283	2·50	23·78	6·15	29·93
„ „ 24, „	35·5	·606	·105	·068	·147	·308	2·44	15·23	5·21	20·44

These numerous analyses show that the sewage of Croydon is much more efficiently purified than that of Norwood. Only on one occasion (August 12th, 1869) during the entire year was the effluent water discharged in a somewhat unsatisfactory condition. On all other occasions the organic carbon and nitrogen were present in proportions considerably below those necessary to render the effluent water an offensive addition to a stream at any season of the year. Suspended matters were never present, except in minute quantity. It must be noticed, however, that during the continuance of the seven nights' frost in January 1869, the purification here, as at Norwood, became markedly impaired, the organic nitrogen increasing from ·186 part in 100,000, at which it stood before the frost, to ·242 part, whilst the assimilation of ammonia by the vegetation was also retarded, as is seen from the increased quantity of ammonia in the effluent water. Unfortunately, the winter of 1868–69 was too mild to permit of this point being satisfactorily tested, and it will therefore be desirable to resume these experiments should there be a longer continuance of frost during the winter of 1869–70. In order to show more clearly the condition of the effluent water from the Norwood and Beddington meadows at different seasons of the year, the following table has been prepared :—

INFLUENCE of SEASON upon the PURIFICATION of SEWAGE by IRRIGATION
RESULTS of ANALYSIS expressed in Parts per 100,000.

Average composition of effluent Sewage Water.	Total Solid Matters in Solution.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	Chlorine.
Spring:							
Norwood - - -	88·1	1·500	·303	·816	·220	1·194	8·37
Croydon - - -	35·4	·594	·104	·072	·225	·388	2·32
Summer:							
Norwood - - -	88·6	1·883	·312	·462	·657	1·361	11·03
Croydon - - -	35·4	·607	·126	·069	·155	·300	2·57
Autumn:							
Norwood - - -	87·0	1·349	·203	·835	·734	1·629	8·04
Croydon - - -	43·1	·690	·138	·185	·589	·792	3·20
Winter:							
Norwood - - -	87·0	1·271	·273	·876	·313	1·255	7·71
Croydon - - -	40·6	·612	·145	·204	·533	·846	2·72
After seven days' frost:							
Norwood - - -	88·8	1·356	·413	1·145	·156	1·534	8·84
Croydon - - -	45·6	·591	·239	·371	·448	·992	2·88

It will be seen from the above table that the total solid matters in solution are remarkably uniform at all seasons; but in estimating the degree of purification effected at different seasons on the two farms, it is necessary to bear in mind the relative strength of the sewage employed in each season, since the purity of the effluent water is considerably affected by the proportion of polluting ingredients in the original sewage; in other words by the strength of that sewage. The strength of sewage is approximately given by the proportion of chlorine which it contains. Estimated by this standard the sewage of Norwood was strongest in summer, whilst the organic elements in the effluent water were also present in largest proportion during the same season. In winter, when the sewage was weakest, the effluent water was purest. At the Croydon farm, on the other hand, the sewage was strongest in autumn and winter, and the effluent water was also less pure in those seasons. In summer, when the sewage was weaker, the effluent water was also purer, whilst in spring, with a still more dilute sewage, the

water leaving the farm attained its highest degree of purity. It follows therefore that the cleansing of sewage is, in the absence of actual frost, less dependent upon season than upon the quality of the sewage itself. It is, however, far otherwise as regards the inorganic (and consequently non-polluting) fertilising constituents,—ammonia, nitrates, and nitrites. These compounds are, as might be expected, removed with greater avidity by vegetation in spring and summer than in autumn and winter. This is clearly seen from the following table, which shows the amount of nitrogen in these three forms left in 100,000 parts of the effluent waters in each of the four seasons, especially if the varying strength of the sewage above mentioned be taken into consideration:—

NITROGEN as NITRATES, NITRITES, and AMMONIA in EFFLUENT SEWAGE.

—	Spring.	Summer.	Autumn.	Winter.
Norwood - - - -	·892	1·026	1·422	1·011
Croydon - - - -	·284	·212	·741	·701

Note.—DETAILS of the CROYDON SEWAGE-FARMS obtained 26th July 1876.

District in which the Lands are situate.	Area in Statute Acres.	
	Irrigated.	Not irrigated.
South Norwood, leased at 10*l.* 0*s.* 0*d.* per acre rental.	55	5
Beddington Farm, leased at 10*l.* 0*s.* 0*d.* per acre rental.	392	63
	447	68

ABSTRACT.

Acres irrigated - - - -	447
Do. not irrigated - - -	68
Total area - - -	515

515 acres of land at per acre rent 10*l.* = 5,150*l.*
Population of the districts, about 56,000.
Annual rateable value of the districts, about 275,000*l.*
Dry-weather flow of sewage used per day, about 3,500,000 gallons.
Storm-water flow, about 15,000,000 gallons.
N.B.—The rental paid for the land for ordinary agricultural purposes was from 26*s.* to 30*s.* per acre.
The crops grown are Italian ryegrass, mangold wurzle, cabbages, and other vegetables. The gross annual income has been about 8,000*l.*
The annual loss or costs in working the farms has been about 2,750*l.*, exclusive of the interest on the expenditure for laying out the farms.

13. *Woking.*—We refer, in conclusion, to an experiment in sewage irrigation on the slopes of poor sandy soil below the invalid prison at Woking. A population of more than 1,000 adults there receive a water-supply of upwards of 20 gallons a head, equal to about one ton daily to every 10 persons. The whole drainage of the place passes through a tank capable of holding about 1,500 cubic feet, or 40 tons of water ; and thence it has hitherto flowed almost entirely to waste, being used, however, in an unsystematic way, to fertilize the grass fields at the foot of the hill. Two acres upon the slope, in four consecutive plots apiece, were laid out in the spring of 1869, so that a tank-full could at any time be poured upon the upper or any other plot of the series, the tail water being directed on any other plot of the series lower down. The four plots of one acre were sown with Italian ryegrass in March, and three crops averaging more than 12 tons each were cut during the following summer, the plant having been repeatedly sewaged during the intervals. The other acre, lying in fallow, was sewaged in the same way, and samples of the effluent water have occasionally been taken both from plots growing ryegrass and from plots without a crop, in the hope that we should ascertain the increased power of a surface covered with a growing crop as compared with one which depended solely on the soil as a filter. The second acre has subsequently been planted with cabbages, potatoes, and mangold-wurtzel, and these crops have received sewage when the plants required. The difficulty of applying the results obtained here to the circumstances of any other case arises from the extreme hollowness and porosity of the Woking soil. A dressing of 40 tons of sewage, poured in three-quarters of an hour from the upper carrier of one of these quarter-acre plots, is, notwithstanding the steepness of the slope, almost all absorbed before it reaches the foot of the plot. It is only when the land is saturated with rain-water, and thus loses its power of absorption, that the sewage-water poured on at top, and conducted over the four plots in succession of the acre then being treated, will reach the bottom of the field. In the interests of the crop it has been therefore necessary to irrigate each plot in succession with raw sewage. The plan has generally been to give each acre so much sewage in the week as to make the result correspond to the allotment of an acre to every 100 persons throughout the year ; and in the further prosecution of the experiment here, when the soil shall have become more clogged with root fibre and with sediment, it is hoped that the effect of the whole acre upon a specified quantity of sewage may be realized and observed. The experiment has also to be extended to other places in order that we may learn from it, if possible, the maximum powers of various soils in cleansing sewage, getting results of the same definiteness in regard to irrigation, as our laboratory experiments have already given us with reference to filtration. Our results at Woking are still incomplete, and must be reserved till the issue of a later report ; but it may be stated as regards the fertilising power of sewage water thus applied, that Italian ryegrass sown in March on poor Woking sand, yielded between July and October three crops of grass, averaging more than 12 tons per acre each ; and that on plots of similar soil the heaviest and most luxuriant growth of savoys, kale, and cabbage has taken place. A bed on which 20 tons of Woking peat had been laid one foot deep and watered in like manner, yielded as abundantly as the rest ; and the result is sufficiently encouraging to justify the prosecution of the experiment on a larger scale, and on peat of a less questionable character, in order to ascertain, in the interests of the great Lancashire towns, whether sewage upon a true bog peat will feed succulent

vegetable growth as successfully as it is found to do on all other kinds of soil.

The Rivers Pollution Commissioners conclude their remarks on some chemical modes of treating town-sewage as under. Irrigation is the only power of cleansing sewage which has stood the test of experience, and, unless it be extensively adopted, there is but little hope of any substantial improvement in our sewage-polluted rivers.

Contrast the chemical methods with the efficiency of irrigation as a utiliser of the manure ingredients of town-sewage. All these ingredients are in this case taken to the land; and three-fourths of them in winter, four-fifths or five-sixths of them in summer, are left there for the use of growing plants; the remainder being rendered unoffensive. These manure materials are thus carried, distributed, and buried; and thus, without the costly labour of the dung cart, manure distributor, or plough, they are brought to the very roots they are to feed; and the fertility they accordingly produce is unexampled otherwise in English agricultural experience. The process can be carried on without offence to any but those who go close to the tanks or channels; and it can be conducted, as the experience of many years at Edinburgh and Croydon proves (*see* Report on *Mersey* and *Ribble* basins, Vol. I., p. 90), without injury to health. We have therefore no hesitation in recommending irrigation as the only plan of dealing with the sewage difficulty at present known to us which at once abates a nuisance and turns to profitable account an otherwise valueless material.

Influence of Sewage Irrigation on Health.

It has often been asserted that sewage irrigation has a detrimental influence on the health of persons living near to or working upon sewage-farms; but nowhere have we found instances of ill-health that are properly attributable to malaria or other causes due to irrigation; and the evidence of Dr. Littlejohn, medical officer to the Board of Supervision in Scotland; Sir Robert Christison, Bart., M.D.; Dr. Ligertwood, staff surgeon; Dr. Alfred Cresswell, and Dr. Alfred Carpenter, given before the Rivers Pollution Commission (see Report, Mersey and Ribble Basins, 1870, pp. 90–91), fully confirms this.

The Craigentinny Meadows.—After bearing testimony to the health of the village of Restalrig, which is surrounded by the sewage meadows of Lochend and Craigentinny, Dr. Littlejohn says:—"I expected that the first part of Edinburgh (Regent Terrace and Carlton Terrace), against which the wind blowing over these meadows impinges, would have exhibited evidence of infection in the shape of cholera or typhoid fever; but I have totally failed to find it so. There are also at Marionville, which is in the very centre of the meadows, a collection of children of the poorest class, who have been kept under the auspices of Dr. Guthrie. Thus the soldiers in the barracks (on the one side, the old people at Restalrig midway, and the very young children with debilitated constitution on the other side) are healthy, With these three delicate tests, including Regent Terrace and Carlton Terrace, we have failed to show that the meadows are prejudicial to health; in fact, opposite evidence might be obtained of a very strong kind."

Dr. Littlejohn informed one of us in January 1876 that he had not anything to add to or retract from the evidence he gave before the Rivers Pollution Commission.

Sir Robert Christison, Bart., M.D., President of the Royal Society

of Edinburgh, in an address on public health in October 1863, speaking of the influence of sewage irrigation on health, said :—"The irrigated meadows in the immediate neighbourhood of Edinburgh, with foul water, are ague-free. They might with reason be strongly suspected, for as managed they present that frequent alternation of considerable moisture and approach to dryness, that rankness of vegetation, and that abundance of decaying organic matter which are thought when combined eminently to foment intermittent and remittent fevers in countries liable to these diseases; but if there be any doubt as to the general salubrity of the now famous meadows of Craigentinny, there is none at least as to the total absence of ague among the inhabitants. I have recently been making careful inquiry respecting this famous and somewhat unsavoury institution. Many years ago my own prejudices were all against the meadows. I have been compelled to surrender them. I am satisfied that neither typhus or enteric fever, nor dysentery nor cholera is to be encountered in or around them, whether in epidemic or non-epidemic seasons, more than in any other agricultural district of the neighbourhood. I think it right in reference to the late introduction of the Craigentinny system of irrigation into the vicinity of other large towns, that these precise facts should be known."

Sir Robert Christison writes to the Secretary to the Commission on the 4th of February 1870, "I have nothing to add to or subtract from the extract from my Social Science address in 1863, quoted above."

Croydon (South Norwood) Sewage-Farm.

"Dr. Alfred Cresswell in his evidence says :—I have resided in the neighbourhood of the South Norwood Sewage Farm since 1866, and have the largest practice there, especially attending the families of those who work on the farm, and who live in houses within 150 yards of the sewage fields. There is also a large school for girls near to the farm. In this school, in which there are more than 30 inmates, there has not been a single case of illness from preventible diseases, and my last quarter's bill was 5*s.* 6*d.* I have not been able to trace a single case of illness to the sewage fields. An unpleasant effluvia does exist, but it is so seldom perceptible that a house built within 200 or 300 yards would command the same rent as if half a mile off. My investigations and independent observations during the last three years have made me an advocate for this method of utilising sewage matter; and as an instance of how perfectly the watery portion is purified, I can state that the water flowing over these fields, and thence conducted into the brook is frequently drank by persons who are ignorant of its source. It is clear, pellucid, and tasteless. Therefore, after watching the working of these fields, my opinion is that when the system of sewage irrigation is well managed the health of the inhabitants in the immediate vicinity is in no way influenced by it."

Croydon (Beddington) Sewage-Farm.

"Dr. Alfred Carpenter says :—The visitor to Beddington will see a number of villas which have been occupied for some years, with irrigated fields both in front and rear, whilst not a trace of enteric disease has appeared in any of them, though I think the Beddington farm is capable of much improvement. It is a farm of nearly 300

acres, lying to the west of the town, and is within 500 yards of a populous portion of it, and also within 900 yards of the centre of the place ; and yet I can safely say that the continuance of a west wind is always accompanied by a diminished amount of ordinary sickness in the place, and our ordinary mortality is generally below 20 per 1,040 At Norwood the population is much greater and much nearer to the fields than at Beddington, probably 400 persons living within 200 or 300 yards of the farm. Previously to its establishment in that district fever abounded ; since then that disease has all but disappeared and the mortality of the district has steadily declined."

Sewage-grown Grass is Wholesome.

On the Liability to Disease which has been alleged to exist from the Consumption of the Milk and Flesh of Cattle fed on Sewage-grown Vegetables.

Dr. Henry D. Littlejohn, in his evidence before the Rivers Pollution Commission at Edinburgh, on September 23rd, 1870, said :—"There are a considerable number of cows kept in Edinburgh and the immediate neighbourhood, and a large quantity of milk is consumed, chiefly obtained from these cows. They are fed with grass that is grown on the Craigentinny meadows. I was of opinion that such grass might be of inferior quality, but I have failed to detect any bad effects resulting from its use. Entozoic disease is remarkably rare in Edinburgh, and tapeworm is hardly ever heard of, except in the cases of persons coming from other places to reside here. Many of the cows which have been fed upon sewage-grown grass are used as food. They are not fattened, because they are always kept in such capital condition; but the cows which have been so fed find their way to our slaughter-houses, where they are examined by inspectors and myself, and, so far as my observations have gone, the use of sewage grass for the food of animals is unobjectionable. Trichiniasis is not known in Edinburgh. If there had been anything in the idea that sewage grass would lead indirectly to entozoic disease, it has had plenty of time to develope itself, and Edinburgh is not only the seat of a great medical school, but medical observation is carried to the highest point so that it could not fail of being detected."

APPENDIX No. VI.

List of Patents more or less connected with Sewage and Manures.

Date.	Number of Patent.	Name of Patentee.	Purpose of Patent.
1856	6	Alexander Cochrane	Conveying and collecting sewage water, &c.
,,	212	Edward Vincent Gardner	Apparatus for heating, drying, evaporating, &c.
,,	974	Thomas Squire and Charles Frederick Claus.	Artificial manure.
,,	1288	William Needham and James Kite.	Expressing moisture from substances.
,,	1579	James Alexander Manning	Manure.
,,	1815	Thomas Wicksteed	Sewage.
,,	1982	George Warriner	Compound for preserving, deodorizing, and fertilizing.
,,	2003	Charles Durand Gardissal	Manure.
,,	2159	Stanislas Chodzko	Manure.
,,	2273	Jean Francois Victor Larnaudes.	Antiseptic and disinfecting mixture.
,,	2289	Duncan Bruce	Manure.
,,	2333	John Gedge	Mineral manure.
,,	2560	Francis Cook Matthews	Manure.
,,	2689	Edward Money	Manure.
,,	2918	Anne Marie Macé	Manure.
,,	2924	Frederick Oldfield Ward and Frederick Wynaut.	Manures.
,,	3000	Joseph Bower	Manufacture of manure.
1857	49	Frederick Herbert Maberly	Receptacles for sewerage.
,,	114	Sir James Murray	Deodorizing sewage matters, manufacture and distribution of manures, &c.
,,	443	James Taylor	Manure.
,,	862	John Ward	Manure.
,,	983	Jean Francois Victor Larnaudès.	Disinfecting and deodorizing animal and vegetable substances.
,,	992	Jasper Wheeler Rogers	Apparatus for the collection of night soil and drainage of houses.
,,	1004	Augustus Edward Schmersahl	Treating bones to obtain gelatine, size, glue, &c.
,,	1069	Thomas Richardson and Manning Prentice.	Manure.
,,	1591	Frederick Oldfield Ward and Frederick Wynauts.	Manufacture of manure, &c.
,,	2206	Robert Clark Gist	Manufacture of manure.
,,	2220	John McMaster and William Wilson.	Manufacture of manure.
,,	2438	Richard Archibald Brooman	Decomposing soapy wash waters, &c.
,,	2627	Edward Owen	Manure.
,,	2645	Charles Walker	Manufacture of manure.
	2949	William Thomas Manning	Treatment of sewerage, &c.
,,	2980	Jean Baptiste Cony	Manufacture of manure and disinfection of animal and vegetable matters.

Date.	Number of Patent.	Name of Patentee.	Purpose of Patent.
1857	3023	Frederick Oldfield Ward -	Manufacture of manure, &c.
,,	3131	Francis Taylor - - - -	Closets or privies.
1858	61	James Alexander Manning	Treatment of sewage and other polluted liquids.
,,	171	Charles Neillon - -	Manufacture of manure from sewage matters.
,,	179	James Alexander Manning	Manufacture of manure.
,,	188	William Edward Newton -	Obtaining and applying compounds of nitrogen.
,,	199	Leon Salles de la Magdaleine	Manure.
,,	287	George Lindsey Blyth -	Manure.
,,	354	Edward Toynbee - -	Manufacture of manure.
,,	400	John Hadfield - -	Manufacture of manure and other products from sewage matters.
,,	665	Isaac Brown and John Brown	Manure.
,,	703	Thomas Greenshields -	Treating ammoniacal liquor, &c.
,,	733	Herman Schwietzer, Joseph Holder, and John Broughton.	Manure.
,,	1245	Robert Owen - -	Waterclosets, night commodes, &c.
,,	1456	James Cane Coombe -	Manufacture of manure from fœcal and other matters.
,,	1499	John Chisholm - -	Treating sewage and other matters, &c.
,,	1549	Constantine Nicolaus Kottula	Manufacture of manure.
,,	1616	Richard Archibald Brooman	Apparatus for the reception and treatment of sewage.
,,	1620	Charles Fréderic Vasserot -	Manure.
,,	1664	William Parsons - -	Separating the solid matter from sewage waters.
,,	1793	Charles Felton Kirkman -	Treating sewage, &c.
,,	1817	Thomas Pickford - -	Manure.
,,	2073	Jean Baptiste Adolphe Dugléré.	Separating solids from liquids for the purpose of disinfection.
,,	2451	Charles Finlay Oliphant Glassford.	Manure.
,,	2977	Thomas Pickford - -	Manure.
1859	183	Thomas Richardson -	Manure.
,,	184	Samuel Osler and John Barton Balcombe.	Manure.
,,	195	André Jacques Amand Gautier, Jean Gilbert Dumay, and Jean Theodore Persin	Manure.
,,	313	Alexander Gopsell Pooley -	Apparatus for manufacturing manure.
,,	447	Prederick William Emerson	Treating ores of lead, &c.
,,	539	The Rev. Henry Moule -	Apparatus for the evaporation of sewage and other waters, &c.
,,	648	John Samuel Dawes -	Collecting night-soil for agricultural purposes.
,,	778	Thomas Carr - -	Machinery for disintegrating artificial manures, &c.
,,	879	Marc Antoine François Mennons.	Treatment of mineral phosphates.
,,	1220	William Edward Gedge -	Manure.
,,	1280	Joseph Gibbs - -	Treatment of coal, &c. for the manufacture of manure.
,,	1368	John Henry Johnson -	Machinery for reducing solid substances to powder.
,,	1388	William Bryer Nation -	Manufacture of superphosphate of lime.
,,	1559	Thomas Bell -	Manure.

Date.	Number of Patent.	Name of Patentee.	Purpose of Patent.
1859	1567	Bridge Standen	Manure.
„	1843	John Dyer Bryant	Superphosphate of lime.
„	1944	Michael John Stark	Manure.
„	2107	Nathaniel Heckford	Purifying rivers and treating night-soil.
„	2157	John Dales	Purification of sewage and other waters, &c.
„	2200	Patrick Robertson	Manure.
„	2218	William Henry Buckland	Preparation of peat.
„	2270	George Long and James Archer.	Manure.
„	2450	John Armour	Apparatus for measuring and regulating the supply of substances in preparing mixtures or compounds.
„	2460	Henry Phillips and James Bannehr.	Manure.
„	2526	William Mannix	Manure.
„	2545	William Clark	Compound for preserving and disinfecting organic substances.
„	2958	Alexander McDougall	Preparation of disinfecting and antiseptic substances.
1860	23	Marc Antoine François Mennons.	Fertilizing compounds.
„	73	Archibald Brounlie	Treatment of sewerage matters.
„	232	Thomas Walker	Cleansing sewage and other waters.
„	404	Joseph Arnold	Manure.
„	703	Thomas Richardson	Treating organic substances containing phosphate of lime.
,	908	Jasper Wheeler Rogers	Collecting excrement and facilitating drainage.
„	1343	James Alexander Manning	Treating sewage, &c.
„	1463	Richard Archibald Brooman	Desiccating fecal matters, &c.
„	2023	William Clark	Manure.
„	2246	William Edward Gedge	Manure.
„	2296	Thomas Richardson Manning Prentice.	Treating phosphotic matters, &c.
„	2482	Jasper Wheeler Rogers	Apparatus for collecting excrement and draining houses.
„	2777	Mathieu Louis Henrionnet and Leopold Octave Boblique.	Treating mineral phosphates of lime.
„	2848	George Henry Cail	Manure.
1861	249	Henry Phillips and James Bannehr.	Urinals; manufacture of manure.
„	424	Thomas Richardson	Manure.
„	684	Jacob Jervell	Manure.
„	876	Francis Taylor	Apparatus for receiving, drying, and deodorizing human excrement.
„	1019	Charles Stevens	Artificial manure.
„	1276	Frederick Oldfield Ward	Manure, &c.
„	2159	Alexandre Jaille	Manure.
„	2229	Charles Felton Kirkman	Obtaining manure from sewage.
„	2351	John Oliver, John Grantham, William Linnock, and Montague Richard Leverson.	Obtaining chemical substances; treatment of vegetable fibre, &c.
„	2525	Thomas Tidmarsh	Manure.
„	2540	Charles Noyes Kernot and Martin Diederich Rucker.	Obtaining ammoniacal salts, &c.

Date.	Number of Patent.	Name of Patentee.	Purpose of Patent.
1861	2871	Frederick Robert Hughes and Thomas Richardson.	Treating saline compounds.
	3265	Thomas Pickford	Manure.
1862	338	Marc Antoine François Mennons.	Treating phosphates of lime.
,,	378	Ditto.	Disinfecting animal excretions.
,,	587	Bridge Standen	Manure, &c.
,,	807	Michael Henry	Kilns, ovens, and furnaces.
,,	908	William Clark	Manure.
,,	1188	William Edward Newton	Fertilizing composition.
,,	1409	James House	Crushing and reducing substances.
,,	1623	William Footman	Treating sewage.
,,	2073	Alexander Morrison Fell	Manufacture of sulphate of ammonia and manure.
,,	2082	Joseph Daniels.	Artificial manure.
,,	2097	William Clark	Manure.
,,	2201	John Richard Nichol	Utilizing and disposing of the sewage of towns and villages.
,,	2569	John Harrop and James Wadsworth.	Deodorizing refuse and fœcal matters for manure.
,,	2712	John Beale and Mary Anne Beale.	Manure.
,,	3011	William Clark	Utilizing refuse azoted matters.
,,	3132	Thomas Walker	Utilizing sewage, &c.
,,	3317	Edward Toynbee	Extracting oils and fatty matters from shoddy, &c. and producing artificial manure.
,,	3449	John Platt and William Richardson.	Disinfecting or pulverizing artificial manures, &c.
1863	132	John Harrop	Manure.
,,	321	James Alexander Manning	Treating night-soil, &c.
,,	606	Thomas Henry Morrell and Joseph Williamson.	Purifying noxious vapours from night-soil, &c.
,,	731	William Lorberg	Treating rags.
,,	761	William Clark	Preparation of manure, &c.
,,	967	Robert Calvert Clapham	Treating waste liquors.
,,	1362	William Clark	Manure.
,,	1435	Henry Martin	Manure.
,,	2208	Thomas Henry Baker and George Friend.	Treating excrementitious and sewage matters.
,,	2294	William Lorberg	Treating rags.
,,	2724	Guillaume Ville	Treating natural phosphates of lime for agricultural purposes.
,,	2731	Jean Augustin Barral and Louise Adolph Cochery.	Manure.
,,	2947	Thomas Carr	Amalgamating, agitating, and dissolving materials.
,,	3152	John Wright	Manufacture of superphosphate of lime.
,,	3264	John Maynes	Manure.
1864	592	Edward Bishop and William Bailey.	Evaporating the water from fœcal matter.
,,	595	James Lee Norton	Manure.
,,	597	John Thomas Way	Manure.
,,	773	James Robbins	Treating substances for producing manure.
,,	955	James Cane Coombe	Manure.
,,	1024	George Jarvis Worssam	Expressing liquids and moisture from substances.
,,	1191	Thomas Walker	Utilizing sewage.

Date.	Number of Patent.	Name of Patentee.	Purpose of Patent.
1864	1408	Thomas Walker - -	Preparing phosphates of ammonia, &c.
,,	2072	Francis Taylor - -	Apparatus for receiving, drying, and deodorizing human excrement.
,,	2329	Thomas Walker and Thomas Ferdinand Walker.	Utilizing sewage.
,,	2788	James Alexander Manning -	Collecting and treating night-soil.
,,	2832	George Edward Noone -	Deodorizing and utilizing sewage.
,,	2840	Jacques Jules Renous Céré	Manure.
,,	3115	William Bardwell - -	Utilizing sewage, &c.
,,	3160	Henry Bird - -	Treating sewage matters.
,,	3161	Stephen Pierre André de Brocalde D' Elüza.	Manure.
,,	3256	Thomas Richardson -	Manure.
865	202	Benjamin King - -	Manure.
,,	451	Richard Smith - -	Treating sewage and ventilating sewers.
,,	512	William Edward Newton -	Artificial manures.
,,	893	William Moxon Fuller -	Reducing waste for manure.
,,	1877	Donald McCrummen -	Artificial guano.
,,	1935	Thomas Spencer - -	Compounds for promoting vegetation.
,,	2626	John Linton - -	Utilizing sewage.
,,	2808	Henry Young Darracott Scott.	Treating and deodorizing sewage water.
,,	2830	George Bartlett - -	Artificial manure.
,,	3115	John Thomlinson - -	Disinfectants.
1866	101	Francis Sutton - -	Treating sewage and urine.
,,	191	Adolphe Francois Mineur -	Manure.
,,	642	Victor Larnaudès - -	Disinfecting and preserving fluid.
,,	773	Alfred George Lock -	Manure.
,,	898	Charles Thieme Liernur -	Collecting sewage, &c.
,,	921	James Davis - -	Utilizing and preventing decomposition of substances.
,,	949	Alfred George Lock -	Manure.
,,	1026	George William Skinner -	Utilizing sewage.
,,	1163	George Edward Noone -	Deodorizing and treating sewage, &c.
,,	2107	Adolph Kühne - -	Purifying water, &c.
,,	2218	Robert Irvine - -	Treating and purifying water.
,,	2606	George William Skinner -	Utilizing sewage.
,,	2750	Francis Taylor - -	Apparatus for receiving, drying, and deodorizing human excrement.
,,	2926	Henri Adrien Bonnneville -	Manure.
,,	2988	James Conyers Morrell -	Dry closets, &c.
,,	3296	Thomas Hoey - -	Flushing waterclosets, &c.
,,	3401	William Bradburn - -	Treating excrementitious matters &c.
867	119	Ernst Süvern - -	Purifying factory and sewage waters.
,,	579	William Parry and John Frearson.	Treating sewage.
,,	729	James Conyers Morrell -	Dry closets.
,,	788	Alfred Henry Hart and William Parry.	Treating sewage.
	933	William Clark - -	Manure.
,,	1229	Emile Grienin - -	Disinfecting fecal matters

Date.	Number of Patent.	Name of Patentee.	Purpose of Patent.
1867	2549	Frederick Tolhausen -	Disinfecting fecal and manuring matters, &c.
,,	2894	Thomas Henry Baker and Thomas Woodroffe.	Treating and purifying sewage.
,,	2918	James Bannehr - -	Supplying deodorizing material to closets, and treating liquid excreta.
,,	3566	Alexander Melville Clark -	Extracting ammonia from fermented and other liquids, &c.
1868	510	William John Bennett and John Jobson.	Filtering sewage, &c.
,,	566	Pierre Nicholas Goux -	Treating and utilizing excreta.
,,	744	William Knox Stuart -	Treating and utilizing sewage.
,,	1954	William Cameron Sillar, Robert George Sillar, and George William Wigner.	Deodorizing sewage for manure.
,,	2666	John Yule - - -	Removing sewage.
,,	2667	William Shang - -	Separating sewage.
,,	2883	William Henry Hughan -	Treating and deodorizing sewage, &c.
,,	2919	Edward Henry Prentice -	Treating sewage, &c.
,,	3087	James Dewar - -	Manure.
,,	3203	Gavin Chapman - -	Treating sewage.
,,	3341	Sigismund-Schuman -	Waterclosets.
,,	3390	Alexander Melville Clark -	Filtering sewage, &c.
,,	3457	Charles Jones - -	Treating sewage.
,,	3562	Thomas Smith and John Van Norden Bazalgette.	Deodorizing and manufacturing manures from sewage, &c.
,,	3714	Alexander Melville Clark -	Compound for disinfecting sewage, &c.
,,	3914	Josiah George Jenning -	Treating sewage and irrrigating land.
1869	506	Frederic Delbreil - -	Removing sewage, &c.
,,	791	Josiah George Jennings -	Preparing sewage for irrigating.
,,	815	James Carter - -	Disinfecting and deodorizing fecal matters, &c.
,,	826	John Thomas Darke -	Treating sewage.
,,	982	Joseph Caldwell Lee -	Collecting and treating excreta.
,,	1103	Edward Charles Cortis Stanford.	Applying, treating, and utilizing materials for deodorising.
,,	1352	Charles Thieme Liernur -	Removing and utilizing sewage.
,,	2016	John Hart - - -	Separating, distributing, and utilizing sewage.
,,	2269	John Henry Johnson -	Manure.
,,	2623	Friedrich Wicke, Julius Brönner, Theodor Petersen, and Johann Georg Zehfuss.	Treating excreta for manure.
,,	3129	Francis Taylor - -	Drying excrement.
,,	3550	Mark French Anderson -	Treating sewage for manure.
1870	67	William Henry Hughan -	Treating sewage, &c.
,,	239	Maxwell Anketell and Oliver Frederick Anketell.	Manufacturing manure and fuel from sewage, &c.
,,	364	George William Wigner -	Treating and purifying sewage.
,,	506	John Leopard - -	Treating and filtering sewage.
,,	580	Alexander Bobrownicki and Alfred Didier Marie Mesnard.	Fuel and manure.
,,	607	David Forbes and Astley Paston Price.	Treating sewage.

Date.	Number of Patent.	Name of Patentee.	Purpose of Patent.
1870	630	James Conyers Morrell -	Treating sewage.
,,	679	George William Wigner -	Centrifugal drying machines.
,,	1061	Thomas James Smith -	Treating sewage, &c.
,,	1137	David Forbes and Astley Paston Price.	Treating sewage and producing manure.
,,	1200	Ludwig Schad - -	Treating excrement.
,,	1311	Robert Weare - -	Treating sewage, &c.
,,	1314	Astley Paston Price -	Treating sewage.
,,	1354	George William Wigner -	Deodorizing and purifying sewage, &c.
,,	1706	Bevan George Sloper -	Treating sewage.
,,	1949	Peter Spence - -	Treating sewage.
,,	2032	Henry Malcolm Ramsay -	Treating sewage, &c.
,,	2047	John Hughes Lloyd -	Utilizing and deodorizing sewage matters.
,,	2048	Charles Bartholomew -	Treating sewage.
,,	2297	Joseph Judge Harp -	Purifying and utilizing sewage.
,,	2534	Ferrar Fenton and Samuel Hollins.	Treating sewage, &c.
,,	2653	Charles Felton Kirkman. -	Treating sewage.
,,	2832	William Frost Sweetland and John Merfield.	Purifying sewage.
,,	2838	Joseph Judge Harp -	Treating sewage.
,,	3107	Amos Bryant and Samuel Hall Culley.	Deodorizing and treating sewage, &c.
,,	3167	Fritze Hillé - -	Manufacture of deodorizing and disinfecting compounds, treatment of sewage, &c.
,,	3169	Henry Young, Darracott Scott.	Treatment of sewage, &c.
,,	3269	Frederick Ludewig, Hahn Danchell.	Treating of sewage.
,,	3399	Christopher Rawson, Philip Ovenden, James Wylde, William McCree and Henry Hill.	Deodorizing and purifying sewage, &c.
1871	297	Proctor Sherwin and John Maude Sutton.	Treating sewage matters, &c.
,,	329	Bevan George Sloper and Felix Jean Joseph Washer.	Treating sewage.
,,	351	Charles Baly - -	Treating sewage, &c.
,,	804	Richard Dover - -	Treating sewage.
,,	1269	Frans Julius Fahlman -	Disinfecting fecal matter.
,,	1469	Adolphus Videky - -	Separating solid from liquid excreta.
,,	1897	Ferrar Fenton - -	Treating sewage, &c.
,,	1969	Edward Taylor - -	Treating excreta, &c. for manufacturing manure.
,,	2109	James Beckett and John James Cam.	Treating sewage.
,,	2140	James Irvine Lupton -	Treating sewage.
,,	2243	Henry Young Darracott Scott.	Treating sewage.
,,	2274	Henry Bright - -	Drying sewage, &c.
,,	2481	Francis Parry. - -	Drying precipitated sewage, &c.
,,	2495	James Banks and William Walker.	Treating and filtering sewage water, &c.
,,	2567	Charles De Chastelain -	Collecting and filtering sewage.
,,	2569	James Burrow - -	Treating sewage, &c.
,,	2696	Robert Milburn and Thomas Browning.	Drying and treating sewage deposit &c.
,,	2760	James Brough Pow -	Treating sewage.

Date.	Number of Patent.	Name of Patentee.	Purpose of Patent.
1871	2841	Daniel Wilks	Collecting and utilizing animal refuse, sewage, &c.
,,	2878	Bendedict John Angell	Treating seaweed.
,,	2926	Adolphe Pierre Vassard	Treating liquid sewage, &c.
,,	2975	Job Cole and William Abbott.	Treating and utilizing sewage. &c.
,,	2997	Hugh Smith	Treating sewage.
,,	3060	William Henry Hughan	Manure.
,,	3233	François Jules Fahlman	Apparatus for treating sewage,&c
,,	3436	James Alfred Wanklyn	Utilizing sewage ammonia.
,,	3515	Henry Young Darracott Scott.	Treating sewage water
1872	379	Francis Gerard Prange and William Whitthread.	Utilizing sewage.
,,	388	Alexander Melville Clarke-	Treating sewage, &c.
,,	448	Silvester Fulda	Clarifying waters, &c.
,,	465	David Carter	Dry earth closets.
,,	575	William Cameron Sillar and Robert George Sillar.	Treating sewage.
,,	671	Robert Blackburn	Treating sewage.
,,	742	John Bailey Denton and Rogers Field.	Regulating intermittent filtration of sewage and irrigation.
,,	849	Henry Young Darracott Scott.	Treating sewage water.
,,	926	Arthur Charles Henderson	Distilling and filtering fecal matters.
,,	944	Dugald Campbell	Treating sewage, &c.
,,	955	William Weldon Symington	Measuring the flow of sewage, &c.
,,	1065	Leos Antoine Badin	Manure.
,,	1327	Thomas Christy the younger	Treating ammoniacal liquor, &c.
,,	1421	James Robey	Filtering medium, &c.
,,	1577	Andrew John Murray	Treating sewage deposits.
,,	1806	William Cameron Sillar, Robert George Sillar, and Christopher Rawson	Treating animal matters.
,,	2141	Henry Syed Copland	Apparatus for mixing and precipitating sewage, &c.
,,	2266	Robert Milburn and Henry Jackson.	Drying and pulverising manure cement, &c.
,,	2279	Isaac Brown	Treating sewage.
,,	2496	Millington Henry Synge	Deodorizing apparatus.
,,	2538	Henry Young Darracott Scott.	Treating sewage.
,,	2687	Bridge Baron Standen	Collecting and treating excrementitious matters.
,,	2991	William Ashop	Drying sewage.
,,	3028	Henry Young Darracott Scott.	Treating sewage.
,,	3215	John Lewis Felix Target	Receivers for waterclosets.
,,	3348	Rogers Field	Sewage tanks.
,,	3355	Henry Young Darracott Scott.	Treating sewage deposits, &c.
,,	3356	James Alexander Manning	Treating fecal matters.
,,	3412	Gustav Alsing	Treating night-soil, &c.
,,	3464	Edwin Hills and Benjamin Biggs.	Treating sewage.
,,	3529	David Curror and James Dewar.	Purifying fluids and manufacturing manures.
,,	3670	Henry Young Darracott Scott and Thomas Walker Scott.	Preparing lime for treating sewage.
,,	3734	William Hart and James Hart.	Drying sewage precipitates, cement, pulp, &c.

Date.	Number of Patent.	Name of Patentee.	Purpose of Patent.
1872	3755	Henry Young Darracott Scott.	Treating and utilizing sewage water.
"	3788	Charles Denton Abel -	Conveying sewage from cesspools, &c.
"	3805	John Rendall and William Rendall.	Slop carts.
"	3821	John Lewis Felix Target -	Collecting and disinfecting sewage excreta.
"	3843	George Haseltine - -	Rendering and drying animal matter, &c.
"	3882	William White Fereday -	Treating excreta for conversion into manure.
"	3913	Leos Antoine Badine -	Closets and apparatus for collecting fœcal matters.
1873	154	Henry Young Darracott Scott.	Treating sewage.
"	168	John Lewis Felix Target -	Treating excreta and sewage.
"	187	Edward Charles Hamilton, William Richard Preston, and Henry Jones.	Manure.
"	230	James Robey - -	Charcoal for purifying sewage, &c.
"	266	Frederick Jacobsen -	Treating sewage.
"	331	Baldwin Latham - -	Purifying sewage.
"	499	George Frederick Chantrell	Receptacle for house refuse, &c.
"	513	Hugh Campbell - -	Manufacture of manure.
"	556	Francis Henry Atkins -	Filtering apparatus.
"	570	Henry Young Darracott Scott.	Treating excreta.
"	712	Thomas Hoey - -	Watercloset apparatus.
"	912	Robert Stevenson Symington	Apparatus for dealing with sewage, &c.
"	957	James Robey and George Frederick Chantrell.	Filtering and deodorizing medium.
"	1319	Gustav Alsing - -	Treating sewage, &c.
"	1445	Henry Young Darracott Scott.	Treating sewage.
"	1509	Do. - - -	Do.
	1555	Walter Brown - -	Treatment of sewage.
"	1686	Eugene Moriarty - -	Treating sewage.
"	1885	Benjamin Green - -	Storing and treatment of sewage.
"	1967	Joseph Townsend - -	Treating sewage.
"	2071	John Leigh - -	Treating sewage, &c.
"	2317	Jeremiah Marsden and John Collins.	Treating sewage.
"	2442	Robert Knott - -	Treating sewage, &c.
"	2450	Edward Charles Hamilton and William Richard Preston.	Artificial manure.
"	2454	Frederick Jacobsen -	Purification of sewage, &c.
"	2532	William White - -	Treating sewage.
"	2534	James Robey - -	Do.
"	2581	John Stephens - -	Treating excreta, &c.
"	2638	John Leigh - - -	Manufacture of manure.
"	2662	Christopher Rawson, William Cameron Sillar, John William Slater, and Thomas Sipling Wilson.	Manufacture of manure.
"	2760	William Henry Hughan -	Treating sewage.
"	2791	Rupert Goodall - -	Treating and clarifying waste water from fulling mills, &c.
"	3168	Charles Thieme Liernur -	Pneumatic drainage works.

Date.	Number of Patent.	Name of Patentee.	Purpose of Patent.
1873	3169	William Whitthread -	Disinfectant and oxydizing agent.
,,	3331	John Towle - -	Treating sewage.
,,	3541	John Hewitt Milnes -	Utilizing sewage.
,,	3632	Alexander Colvin Fraser and William Watson.	Treating and utilizing sewage.
,,	3742	Henry Young Darracott Scott.	Treating sewage water.
,,	3781	William White - -	Precipitating sewage and other foul waters, &c.
	3833	Benjamin Green - -	Storing and treating sewage.
,,	4092	Henry Malcolm Ramsay -	Treating sewage.
,,	4284	John James Bodmer -	Drying peat, sewage deposit, &c.
1874	50	William Alfred Gibbs -	Drying apparatus.
,,	160	Augustus Edward Schmersahl.	Treating sewage.
,,	283	Henry Young Darracott Scott and John Berger Spence.	Treating sewage, &c.
,,	653	Henry Young Darracott Scott.	Treating sewage for manure.
,,	848	Rupert Goodall - -	Purifying foul water or sewage.
,,	1171	Thomas Short - -	Purifying sewage.
,,	1415	William Robert Lake -	Deodorizing and utilizing sewage.
,,	1426	John Towle - -	Collecting, treating, and distributing sewage.
,,	1453	Daniel Kinnear Clark -	Disintegrating and straining apparatus.
,,	1689	Gustav Alsing - -	Utilizing sewage for manufacturing artificial fuel.
,,	1764	John Howard Kidd -	Deodorising sewage and making artificial manure.
,,	1826	Rupert Goodall - -	Clarifying sewage, &c.
,,	1916	John Henry Johnson -	Filtering sewage, &c.
,,	1959	William Henry Hughan -	Treatment of sewage, &c.
,,	2408	Samuel Hallsworth and Richard Bailes.	Clarifying waste water, sewage, &c.
,,	2439	Augustus Edward Schmersahl.	Treating sewage.
,,	2446	William Alexander Lyttle -	Treating sewage.
,,	2450	Henry Young Darracott Scott.	Recovering ammonia for sewage.
,,	2461	William Spence - -	Treating sewage.
,,	2567	Feorge Willett, Robert James Harris, and James Lund.	Filtering sewage.
,,	2676	James Alexander Manning -	Dry closets, &c.
,,	3122	Bridge Baron Standen -	Treating excrement.
,,	3199	John Howard Kidd -	Treating sewage for manufacturing manure.
,,	3225	James Mc. Intyre - -	Purifying sewage waters.
,,	3326	Francis Thomas Bond -	Treating liquid refuse, &c.
,,	3384	Francois Alcidi Bonnefin -	Treating excrementa.
,,	3459	Samuel Hallsworth and Richard Bailes.	Treating and clarifying sewage, &c.
,,	3751	George Mackay - -	Purifying liquids.
,,	3784	Burton Henry Valle -	Treating sewage.
,,	4158	Rupert Goodall - -	Clarifying impure water or sewage.
,,	4247	James Conyers Morrell -	Sewer pipes, &c.
,,	4305	Henry Young Darracott Scott.	Treatment of sewage.

Date.	Number of Patent.	Name of Patentee.	Purpose of Patent.
1875	150	George Rydill - -	Purifying sewage, &c.
,,	214	John Box, Edouard Aubertin, Leopold Boblique, and Hypolite Leplay.	Disinfection of sewage, &c.
,,	373	Henry Young Darracott Scott.	Manures.
,,	399	George Rydill - -	Treating sewage.
,,	573	Samuel Hallsworth and Richard Bailles.	Clarifying sewage, &c.
,,	1195	Francis George Whitwharn	Treating excreta.
,,	1216	William Edward Newton -	Treating fecal matters, &c.
,,	1335	William Morgan-Brown -	Treating sewage.
,,	1625	Thomas Pape - -	Filtering and deodorizing sewage.
,,	1759	John Yale - - -	Barge for receiving and conveying sewage.
,,	1845	Mark French Anderson -	Treating sewage.
,,	1954	Joseph James Coleman -	Treating sewage.
,,	1972	Daniel Wilks - -	Collecting and treating sewage.
,,	2358	James Odams and Robert Blackburn.	Apparatus for treating sewage.
,,	2557	Frederick William Granham	Filters.
,,	2621	David Gill - - -	Deodorizing sewer gas.
,,	2675	John Hanson - -	Treating sewage.
,,	2798	Joseph Robinson - -	Discharge of sewage from towns.
,,	2829	Thomas Stevens - -	Treating sewage.
,,	3162	Alexander Melville Clark -	Treating sewage.

APPENDIX No. VII.

Abstracts from the Reports of Royal Commission, and others, who have inquired into the best Modes of Distributing the Sewage of Towns and of applying it to beneficial and profitable Uses.

The following extracts are taken from published reports which are now out of print, and which consequently cannot be made generally available. On referring to them, it will be seen that there are detailed statements, as also conclusions and recommendations, which have as much value now as at the time they were made. Our more recent examinations of towns, sewage farms, and the several modes of treating sewage, confirm the conclusions almost to the letter. We therefore point to these extracts as justifying our own conclusions.

Extracts from the Reports of the Royal Commission.

Precipitation of the Solid Matter of Sewage.

Of the different processes that have been proposed for the precipitation of sewage, that by lime is the simplest. It is also the only one that has hitherto been put into practical operation to any considerable extent, and we may be therefore allowed, without disparagement to other methods, to select it as a type for illustration of the whole.

The use of lime to separate the solid matters of sewage is founded on the following circumstances. Sewage of itself, from the slimy, glutinous character of the matter floating in it, and from the specific weight of that matter being so nearly the same with water, will only separate very imperfectly, and after a length of time, into a clear liquid and a solid deposit.

The addition of lime, however, by the chemical changes which it induces, but which we need not here describe, causes a separation of the solid suspended matter in a state of flocculence, in the same way that white of egg clears coffee or isinglass fines beer.

The result is that the sewage rapidly changes its character, separating readily into a deposit, which falls to the bottom, leaving a clear liquid. This is essentially the process that is carried on at Leicester, Tottenham, and other places, the two named being the most important. The clear liquid after subsidence of the solid matter is considered comparatively pure and unobjectionable, and is allowed to flow into the rivers. The solid is drained, as far as possible, and finally dried, and then offered for sale as manure.

We may state our belief that, as far as present knowledge goes, that is, up to 1858, this very simple process offers as much prospect of commercial advantage in respect to the manufacture of a solid manure from sewage as any patent process that has been proposed up to this date.

But with reference to the prospect of obtaining any very large profit from the treatment of sewage, we see no reason to dissent from the view that has been individually held and promulgated by several of our members, namely, that neither the lime process nor any other existing method of precipitating sewage is likely to be commercially advantageous to those who engage in it. We consider that this is, however, not the light in which the matter should be viewed. The great problem is to get rid of sewage advantageously to agriculture, if it may be; if not, at the least expense to the community at large.

Throughout the discussions that have hitherto occurred upon this question, the real issue has been left comparatively in abeyance. The

primary consideration is not whether sewage can be made serviceable to agriculture, but whether or not there exists any method which, consistently with a fair expenditure of money, falling on those who ought in justice to bear it, will practically rid us of the nuisance and danger attendant upon town sewage.

The object must be accomplished, and the question is, simply, how its accomplishment can most satisfactorily be attained. All other considerations are secondary to this. The process of precipitation by lime, as carried out at Tottenham, and on a larger scale at Leicester, is satisfactory up to a certain point. The solid matter of the sewage is effectually separated, and a clear and comparatively innocuous liquid is run off. We shall presently consider the objections that have been urged against this liquid, but we wish now to point out that any nuisance which is chargeable to works such as those at Leicester and Tottenham is due, not to the act of precipitation, but to the process employed for drying the solid matter into a condition fit for sale. At both the establishments in question the sewage is received and treated in closed or covered tanks, and, as the lime considerably diminishes the smell of the sewage, the whole operation can be carried on, and the clear liquid run off, without offence. But the solid deposit which settles down in the form of a thick sludge must be removed, and must in some way be dried. This part of the operation is very difficult; it requires much space, and the value of the product is too small to allow of the drying being entirely effected by artificial heat. Consequently, both at Tottenham and Leicester, we found great pits and mounds of this sludge undergoing a gradual process of draining and drying in the open air; and it is to these accumulations of the precipitated matter of sewage, exposed to the sun and other agencies, that the offensive smells must be attributed, which sometimes, but not always, are perceptible from the works.

As an inexpensive means of avoiding nuisance, we may here advert to the simple process adopted by the Local Board of Health at Cheltenham for separating and disposing of the solid matters of sewage in conjunction with the use of lime, which has been attended with considerable success. This method seems likely to be made available in many other places with advantage.

The chief portion of the solid matter is separated in tanks by deposition and a coarse filtration or straining process, the liquid flowing off is then treated with lime in order to diminish the smell and to precipitate the finer particles in suspension in the water before it is allowed to flow into the stream. The deposit or sludge first obtained is mixed with ashes and scavenger's refuse of the town, and thus a solid manure is formed which has been bought by the farmers in the neighbourhood at 2*s.* 6*d.* per cubit yard. A charge of 3*s.* 6*d.* per cubic yard would pay all working expenses and interest on the outlay, and it is thought that this price might be obtained for it; but one most desirable and necessary thing is to have a regular and speedy removal from the ground.

With regard to the liquid which results from the operation of liming sewage, its frequent examination by different chemists has proved, what would in fact have been anticipated, that it contains a considerable quantity of dissolved matter of a vegetable and animal origin which the lime is incapable of separating; a certain amount of smell also remains, although by no means the same in kind or degree as the crude sewage.

In the report of Dr. Hoffman and Mr. Witt, addressed to the referees on metropolitan drainage, the subject of these precipitating processes has been discussed at some length. These gentlemen have arrived at the conclusion that, inasmuch as a quantity of "putrescible" matter is left in

the liquid resulting from liming the sewage, and that this liquid when kept during warm weather is liable to become a second time offensive to the senses and consequently dangerous to health, such process is not admissible in the case of the metropolis. But we submit that the question is not whether, in the abstract, sewage after treatment with lime contains vegetable and animal matters in solution, and is liable to further putrefaction, but whether such treatment so far destroys the noxious character of sewage that practically it may be thrown into rivers without danger.

Without going so far as to say that the precipitation by lime is a perfect process, or that it can in all cases be adopted, we feel satisfied that it does to a great extent fulfil the purpose for which it is employed, so far, at least, as the purification of rivers is concerned.

By far the largest amount of nuisance and danger arising from the pollution of rivers by sewage is due to the solid suspended matters which give off noxious effluvia throughout the period of their decomposition. This is especially the case in our tidal rivers, where these deposits form shoals and cover the banks, and at low water offer a vast surface of offensive matter for the contamination of the air. The lime process does effectually remove this gross solid suspended matter, and in so far accomplishes a great and manifest good. It also destroys the immediate influence of the noxious gases in sewage, and although it may, in the abstract, be open to the objection of still leaving matter capable of further putrefaction in the liquid, we are of opinion that wherever this liquid is thrown into a body of water considerably larger than itself (not less than 20 times the volume of the clarified sewage) no evil results will practically be experienced.

Our conclusion, then, is, that in the absence of means for a direct application of sewage to land, the methods of precipitation at command by lime do actually offer remedial measures of a satisfactory character. It remains to consider whether these remedial measures are within the fair limits to which a town population may be taxed for the suppression of the sewage nuisance.

We have already stated our belief that unless some new process of greater efficiency should be discovered, the formation of a solid manure from sewage will not be remunerative; that is to say, that the amount realized by the sale of the manure will fall short of the cost of its production. Neither is this to be considered as a condition dependent on the want of appreciation of the manure, which time and better information on the part of the consumer will remove; on the contrary, the tendency has been hitherto to put the price above the value which a sound acquaintance with the nature of manures would attach to it. It is even questionable whether, in some instances, any money at all would be given for this deposit, and in considering the practicability of carrying into effect plans for the precipitation of sewage we must be prepared for this eventuality.

It will therefore be placing the matter in a necessary, although the least favourable, light, if we consider that the manure when made possesses only so much value as to induce farmers to cart it away without paying for it. It may be desirable, however, that we should here advert to a plan by which the expenses attendant on these precipitating processes would be very materially reduced, and the necessity for works for this purpose in the vicinity of towns, and the possible nuisance or fear of nuisance to which they might give rise, would be entirely obviated. This plan is to limit the process to the precipitation of sewage, and after allowing the clear liquid to run off, to pump the sludge or mixture of deposited matter and water directly on to the fields through pipes.

Remarks.—This process of pumping sewage-sludge direct from the tanks where it is deposited to the land is practised at Birmingham. The sludge is spread over land to the extent of one statute acre per week, and is trenched or dug in at a cost of 14*l.* 10*s.* per acre. In this position the water absorbs or evaporates, and leaves the dried earthy matter in the soil. After the interval of a year the land can be used for farming purposes. The sludge as pumped contains about 90 per cent. of water, which dries away in about 12 months' time.

It has already been stated that the chief source of nuisance, or liability to nuisance, in such works consists in the necessity for drying the sludge, and a very large portion of the original outlay for works and the area required for such works, and of the daily expenses, is involved in this part of the operation. By the plan above mentioned all these difficulties would be materially reduced, the works would be confined to the precipitating tanks and the engine for pumping, and neither the sewage nor the deposit would see the light of day before the clarified water was discharged in a comparatively innocuous state into the rivers, and the sludge was deposited on the fields.

It has been calculated that the quantity of sludge to be pumped would not exceed 5 per cent. of the whole sewage, so that the cost of applying it would be small in comparison with that of distributing the whole sewage on the land.

Remarks.—The Commissioners did not apparently anticipate the cost of digging in the sludge at 14*l.* 10*s.* per acre, and the loss of at least one year's rent of the land.

We have already stated that the processes for separating the solid matter do not realize the agricultural value of the sewage. It has long been understood that at least four fifths of the substances valuable in relation to vegetation pass away with the water; the solid matter, therefore, which in this plan would be pumped on the land, would not fertilize so large an area as the whole sewage; but in relation to the necessary disposal of sewage, which it is our duty to keep steadily in view, this circumstance would offer some advantages, inasmuch as it would in many cases be much easier for town authorities to find the smaller area of land upon which it might be applied than that extensive space which the whole sewage would require. Other modifications in carrying out this system will readily present themselves.

The two methods for the disposal of sewage, that is to say, by direct application to land, or by precipitating processes, have been, perhaps, sufficiently considered. It is almost unnecessary to add that they can be worked conjointly, and in some cases such a plan would be attended with advantage. Thus, for instance, where opportunities occurred for the disposal of a part of the sewage for direct application, though the whole could not immediately be so got rid of, the remainder might be treated by methods of precipitation.

The erection of works for the latter purpose would obviate the present nuisance, and give time for that change of opinion which will ultimately cause the sewage to be sought after by agriculturists.

Moreover, in many cases the previous separation of the solid matter may increase the facilities for liquid application, allowing of the use of large quantities by open irrigation on a limited area without the risk of nuisance.

Remarks.—The land filtering process will enable large volumes of clarified sewage to be filtered on small areas, 2,000 persons to one acre.

It remains now only to revert to one point in relation to the character of the liquid after these precipitations of sewage have been effected.

It has been already mentioned that objections have been taken to lime

and other similar processes, on the score that the liquid is liable to become again putrid. We have stated that we believe this circumstance to be practically unimportant, but, as it is a wise policy in all cases to avoid even the occasion of offence, it is very desirable that even this objection should be overcome. If, after the separation of the solid matters by lime or other precipitants, any further treatment of the clear liquid would place it in a condition in which ulterior change involving the production of offensive and noxious smells would be impossible, the problem, both in a theoretical and practical sense, would be most completely solved.

We are of opinion that the accomplishment of this object is quite within the means of chemical science, and we feel ourselves justified in expressing this conviction from the results of experiments which have already been made in presence of some members of the Commission, although our investigation of this point is not yet complete.

From the whole of our inquiry we have arrived at the following conclusions:—

Preliminary Report, March 1858.

Conclusions.

1st. That the increasing pollution of the rivers and streams of the country is an evil of national importance, which urgently demands the application of remedial measures; that the discharge of sewage and other noxious refuse of factories into rivers is a source of nuisance and danger to health; that it acts injuriously not only on the locality where it occurs, but also on the population of the districts through which the polluted rivers flow; that it poisons the water, which in many cases forms the sole supply of the population for all purposes; that it destroys fish; and, generally, that it impairs the value and the natural advantages derived from rivers and streams of water.

2nd. That this evil has largely increased with the growing cleanliness and internal improvements of towns as regards water-supply and drainage; that its increase will continue to be in direct proportion to such improvements, and that as these improvements are yet very partial, the nuisance of sewage, already very sensibly felt, is extremely slight as compared to what it will become when sewerage and drainage works have been carried into full effect.

3rd. That, in many towns, measures for improved water-supply and sewerage are retarded from the difficulties of disposing of the increased sewage which would result from them; that the law which regulates the rights of outfall is in an anomalous and undefined condition; that judicial decisions of a conflicting character have been arrived at in different instances; and, that consequently the authorities of towns have constantly before them the fear of harassing litigation.

4th. That the methods which have been adopted with the view of dealing with sewage are of two kinds: the one being the application of the whole sewage in its crude state to land; and the other, that of treating it by chemical processes, to separate its most offensive portions; that the direct application of sewage to land favourably situated, if judiciously carried out, and confined to a suitable area, is profitable to persons so employing it; that where the conditions are unfavourable, a small payment on the part of the local authorities will restore the balance.

5th. That this method of sewage application, conducted with moderate care, is not productive of nuisance or injury to health.

6th. That when circumstances prevent the disposal of crude sewage

by direct application to land, the processes of precipitation will greatly ameliorate and practically obviate the evils of sewage-outfalls, where there is the sea, or a large river for the discharge of the liquid; that such methods of treating sewage do not retain more than a comparatively small portion of the fertilising matter; and, that although in some cases the sale of the manure may repay a portion of the cost of production, solid manure manufacture is not likely to be successful commercially.

7th. That, considered merely as the means of mitigating a nuisance, these precipitating processes are satisfactory; that the cost of them in any case is such as town populations may reasonably be called upon to meet; that the necessary works need not, if properly conducted, be a source of nuisance, and that, by modifications of the existing methods, even the slightest risk of nuisance may be entirely obviated.

8th. That the employment of the one or other method of disposing of sewage, or of both conjoined, must depend upon locality, levels, markets, and a variety of other circumstances, and that the case of each town must be considered upon its own peculiarities.

9th. That there is good ground for believing that the methods yet proposed for dealing with sewage are not the best that can be devised, and that further investigation will probably result in the discovery of processes more thoroughly equal to the suppression of nuisance, and at the same time calculated to give more valuable products.

10. That the magnitude of a town presents no real difficulty to the effectual treatment of its sewage, provided it be considered as a collection of smaller towns.

As, however, the conditions under which the evil may be best removed will differ greatly in different localities, we think it would be desirable, before any legislation takes place on this subject, that investigation should be made into the state of the outfalls of different classes of towns, and of the condition of rivers in populous districts, with the view to advise as to the general legislative measures that might safely be adopted.

Westminster, 26th March 1858.

Second Report, 1861.

Conclusions.

We submit the following conclusions as the result of these our further investigations:—

1. That the pollution of the rivers of the country is so great and general as to have become a national evil.

2. That this pollution has progressively increased in recent years, is still rapidly increasing, and, unless arrested, must necessarily continue to do so in proportion to the increase of population, the progress of town sewering and house drainage, and the extension of manufactures.

3. That although one of the chief causes of this pollution is the practice of discharging crude sewage, as it comes from towns, into the nearest rivers or watercourses, thus converting them into sewers, yet, the pollution from this cause is by no means confined to towns which have adopted systematic measures for improved sewerage. Nor is the amount of pollution in proportion exclusively to the completeness of such works; for, in many of the towns in which the bulk of the foul refuse is still retained in cesspools and middens, the neighbouring rivers are in a highly offensive and noxious condition,—even where the cesspool

system is maintained on the alleged ground of preserving the local rivers from contamination.

4. That besides the pollution of rivers by the discharge of sewage into them, they are in general made the common and ready receptacles of an immense amount of offensive matter from factories, dye-works, gasworks, iron foundries, mills and other establishments, while cinder-heaps and masses of rubbish of every description that cover their banks, and the large stones and other refuse that obstruct the beds, testify to the general neglect and ill-usage of rivers.

5. That by far the greater part of the solid matter which is held in suspension in water is readily deposited in rivers, covering the banks with mud, permanently raising the beds, gradually destroying the scouring power of the water, and partially silting such rivers up ; and that in some instances these deposits have accumulated to such an extent as to impede navigation, to render the surrounding country subject to floods, and to entail a vast expense in periodic cleansing.

6. That however the appearance of the water may be improved after these deposits have taken place, yet the deposited matters, lying in the bed of the current, are under conditions favourable for putrefaction. And when the foul mud is disturbed by the prevalence of rain, and during floods, it sends forth its effluvia amidst the populations which are near, and even in the course of the rivers far distant.

7. That this condition of rivers is a public and national nuisance; it interferes with the convenience and comfort of all classes of the people ; it damages various and important interests, as those connected with manufacturing establishments, canals, fisheries, and so on ; it deteriorates property to a large extent; and, as interfering with a main source of water supply, is of serious detriment to the public health.

8. That this state of things has grown up in consequence of the anomaly that while important powers of river conservancy have from time immemorial been conferred on local authorities, while special powers have been vested in Improvement Commissioners and companies for isolated local improvement, for drainage, for navigation, and so on, and while even private water-rights and ownerships in streams have been recognized and conferred, no general jurisdiction whatever has been exercised over the whole waters of the country ; no protection has been accorded to the many great and varied interests connected with rivers.

9. That the only way of restoring rivers to their original purity is to prevent the discharge of foul matters into them, and especially the discharge of sewage and other refuse of large towns ; but that, in various cases where this treatment has been deemed inadmissible, expedients for the purpose of depriving the sewage of its offensive and noxious properties have been brought into practical operation, and have been attended with more or less success.

10. That among those methods of which experience is most satisfactory no one is suited to the circumstances of all towns, some towns presenting much greater difficulties than others ; yet the more this subject has been investigated the more convincing is the evidence that there is no town which might not, with reasonable care and at moderate cost, greatly mitigate existing evils where it may not be practicable wholly to remove them.

11. That, for example, the chief part of the nuisance arising from the discharge of sewage into rivers and streams may be obviated at once by simply arresting the solid matter in suspension in the liquid, particularly in towns of small populations where the sewers discharge into considerable streams of water. In these cases it may be practically sufficient to adopt simple means of deposit, combined with mechanical

appliances for arresting solid matters, and these may be of the most inexpensive character; in other cases, however, and especially during summer, the addition of chemical agents may be required for the more complete separation of solids, and the deodorising of liquid sewage. But although, by such means as the above, sewage may be rendered inoffensive to smell, we cannot guarantee that, even after the best practicable application of such means, sewage can be allowed to flow into any brooks or rivers without rendering the waters unsafe and improper for drinking.

12. That among deodorizers, the material which up to the present time has been found the best for this purpose is *perchloride of iron*, the only objection to its general use being its comparatively high price; but in many cases the employment of the cheaper material, lime, may suffice.

13. That the value of the solid portions of sewage being small, all attempts at realizing profits from its preparation as manure have signally failed; but, mixed with ashes, sweepings, and other dry refuse of towns, sale is found for it at 2*s*. or 3*s*. per ton, which is sufficient to pay a proportion of the necessary working expenses of mixing.

14. That the cost of the operation has in various instances ranged from $\frac{1}{2}d$. to 3*d*. per head of the population per annum, including interest on the outlay for works; there can therefore be no difficulty on the ground of expense in requiring the adoption of adequate means for a removal of nuisance in every case in which injury or inconvience is shown to arise.

15. That the most beneficial and most profitable method of disposing of sewage, where circumstances will admit of this use of it, is by direct application in the liquid form to land; where such applications can only be conveniently effected near habitations, it may be desirable to employ some deodorizing agent; but usually, if proper arrangements are made for conveying sewage on the land, this expense need not be incurred.

There is reason to hope that trials and experiments instituted by the Commission, and still in progress, in relation to the irrigation of land with sewage, will remove some doubts and difficulties which have hitherto prevailed in retarding a more general adoption of this desirable mode of disposing of and utilising the sewage of towns.

Recommendation.

Having now fully stated our conclusions as to the means of disposing of the sewage of towns, and shown that the remedies for the evils which are experienced, although various, are both practicable and economical, we beg to repeat our conviction that the only security for a general and continued employment of such means will be the establishment of responsible conservancies throughout the country, armed with adequate powers for preventing damage and for effecting improvements. We believe that these powers would be best vested in independent local authorities, such as the present Commissioners of Sewers; acting under certain Government regulations in respect to borrowing money, and other matters. Our inquiry, however, has of necessity been of too imperfect a character to enable us to set forth for consideration any decided measures in detail on so large and important a question. There are many subjects to be inquired into, and vast interests to be considered, which are beyond our present power or our province to enter upon. We can only respectfully but earnestly recommend that such inquiries should

be instituted into the various points bearing on the subject, so that measures may be submitted which will enable Parliament to deal with the existing evils in a way most conducive to public interests.

Whitehall, August 1861.

Third Report of the Royal Commission.

Conclusions.

To the Lords Commissioners of Her Majesty's Treasury.

May it please Your Lordships, March 1865.

We, the undersigned, whom Her Majesty's Commission, bearing date 5th January 1857, appointed to inquire into the best mode of distributing the sewage of towns, and applying it to beneficial and profitable uses, have now again, according to our instructions, the honour of reporting to your Lordships our further progress in the matter committed to us for inquiry.

Since the date of our last Report (August 1861) we have, through a committee of our number consisting of Mr. Lawes and Professor Way, continued at Rugby the experiments which were undertaken in 1861 on the application of sewage to land. The report of that committee, which we append, contains the results for the three years 1862–4.

Your Lordships will observe that these experiments have not been confined to the application of sewage in different quantities to land, but have extended to the consumption by cattle of the produce so obtained, and to the production of meat and milk, and have been accompanied by a careful record of the quantities and market value of the products, and by numerous analysis of the sewage before and after irrigation, as also of the grass and of the milk.

It appears to us that these experiments have solved many of the difficulties which have hitherto attached to the question of the agricultural application of sewage, and that they leave no reasonable doubt of the practicability and advantage of so employing the sewage of towns.

We have also continued to give our best attention to all kindred experiments and inquiries which have been going on elsewhere.

As the results of our labours, extending over eight years, we have confidence in submitting to your Lordships the following conclusions:—

1. The right of way to dispose of town sewage is to apply it continuously to land, and it is only by such application that the pollution of rivers can be avoided.
2. The financial results of a continuous application of sewage to land differ under different local circumstances; first, because in some places irrigation can be effected by gravity, while in other places more or less pumping must be employed; secondly, because heavy soils (which in given localities may alone be available for the purpose) are less fit than light soils for continuous irrigation by sewage.
3. Where local circumstances are favourable, and undue expenditure is avoided, towns may derive profit, more or less considerable, from applying their sewage in agriculture. Under opposite circumstances, there may not be a balance of profit; but even in such cases a rate in aid, required to cover any loss, needs not be of large amount.

Finally, on the basis of the above conclusions, we further beg leave

to express to your Lordships that, in our judgment, the following two principles are established for legislative application :—

First, that wherever rivers are polluted by a discharge of town sewage into them, the towns may reasonably be required to desist from causing that public nuisance :

Second, that where town populations are injured or endangered in health by a retention of cesspool matter among them, the towns may reasonably be required to provide a system of sewers for its removal.

And should the law, as it stands, be found insufficient to enable towns to take land for sewage application, it would, in our opinion, be expedient that the Legislature should give them powers for that purpose.

Whitehall, 1865.

EXTRACT from a REPORT by HENRY AUSTIN, Esq., C.E., prepared for the ROYAL SEWAGE COMMISSION.

Mr. Henry Austin, Chief Inspector of the Board of Health, was also a member of the Royal Sewage Commission, and was requested to prepare a Report for the Commission, of which these are the conclusions :—

As the result of my inquiries, and of the best attention which I have been enabled to afford to this important subject, I beg to submit the following conclusions :—

CONCLUSIONS.

1. That although from the earliest agitation of the question of sanitary reform, and of the complete drainage of towns, the mischief from pollution of rivers on the one hand, and the waste of valuable manure on the other, by the direct discharge of the sewage, was insisted upon, no conception was at any time formed of the extent of the evil which now so imperatively calls for remedy.

2. That although the means of remedy by deodorization appear to be as yet but imperfectly understood, and demand further investigation, various processes have for a long time been in more or less successful use for this purpose. That the employment of some of these, known to be destructive of the fertilizing power of sewage, would involve expense without any return, and although such expense, if unavoidable, should unhesitatingly be incurred to avoid any permanent danger to the population, it appears that other deodorizing materials are not destructive of that fertilizing power. That it is most important, therefore, to determine whether the fertilizing elements in the refuse are presented in such form as to be practically available for agriculture, either in the solid state or in the liquid form, so as to avoid the injurious consequences and enormous waste of throwing away the sewage.

3. That the nature and value of the chemical constituents of the fœcal matter in sewage having long been known to physiologists and chemists, and admitted to contain all the elements necessary for the food of plants, the recent discussions as to its practical value for agriculture have not arisen from any doubts on that point, but from the uncertainty whether, being diluted in the large bodies of water employed for the drainage of towns, that value is realizable.

4. That chemical research has not yet arrived at any satisfactory

method of economically arresting from solution the fertilizing ingredients in sewage, while the analyses of solid sewage manures, manufactured under various patents, show that, although for the most part possessing a certain low value, they do not justify the high prices at which they have been offered to the public; nor does there appear to be evidence of any agricultural results derived from their use which will support such a view of their value.

5. That the manufacture from excrement of a dry portable manure, as practised at Paris, although realising results of greater value, is applicable only where the cesspool system prevails, and leads to an aggravation of the nuisance of that system, which due regard for the public health would not tolerate.

6. That the separate system of drainage, frequently proposed as a solution of the sanitary and agricultural difficulties of the sewage question, would increase immensely the cost of drainage works, would add to the sources of danger to the public health, and would tend to a waste of fertilizing power.

7. That the practical experience obtained during many years at Edinburgh and Milan has shown the great value of sewer-water on grass lands, although applied in a state of great dilution; while valuable experiments have shown the power of soils to remove from solution, and retain for vegetation, the fertilizing elements.

8. That notwithstanding the enormous quantities of sewage-water which have been applied to the land at Edinburgh, the produce is said to be always in corresponding ratio to such quantity, and that the limits of quantity to be applied, and of produce to be realised, have not yet been ascertained.

9. That the precise value of the manure in a given quantity of sewer-water may be readily determined, and, therefore, that the corresponding quantity of water which must be applied to convey a certain required quantity of such manuring elements on to the land may be at any time known.

10. That although such immense agricultural results have been obtained from irrigation with sewage-water at Edinburgh, the method employed has given rise to much complaint of nuisance. That this arises for the most part from foul deposits in wide ditches, and from the large evaporating surfaces of the sewage constantly exposed in the channels of irrigation.

11. That all such sources of nuisance and danger are preventible, and should not be tolerated. That no ditches should be used, and that the sewage should be exposed only during the act of irrigation of each portion of the land, when it would be immediately absorbed and deodorized by the soil.

12. That in order to avoid all further risk of injury to health, whether from discharge of the sewage into the rivers and streams, or from its application to the land, it appears desirable that the solid matter should in every case be separated from the liquid sewage at the outfall, and that a cheap, portable manure should be manufactured therefrom for use in the immediate neighbourhood, as practised at Cheltenham. That it should be mixed with the ashes of the town, or such other deodorizing material as may be most suitable for application to the surrounding land, and prepared, if desirable, with other manuring ingredients for particular crops.

13. That it appears probable that such operation will, in most places, pay its own expenses; but that as some such measure is absolutely necessary for the public health, even though involving some expense, it

should be the duty of local boards and other governing bodies to carry it out, just as much as arrangements devolving upon them for removal of dust or other refuse from the town. It should form, in fact, part of such service, and might be combined in the same contract.

14. That the liquid portion of the sewage, thus cleared of its solid matter, but still retaining its chief value as manure, might then be applied with benefit to the neighbouring lands in any quantity; but that all land upon which this method of application of the sewage is practised should, if not naturally porous, be artificially drained, as the liquid, if allowed to become stagnant, would, as in common irrigation, be likely to engender disease in the neighbouring inhabitants or in cattle exposed to its influence.

15. That the distribution of manures in the liquid state by the hose and jet, from a system of underground pipes on the land, has been found, by the experience of several years upon farms in England and Scotland, most advantageous, and that the outlay for such works is considered by eminent agriculturists who have had experience of their benefits, as a very profitable outlay, irrespective altogether of the question of sewage distribution.

16. That although the adoption of the the same system at Rugby and other places for the distribution of liquid sewage has been found decidedly successful, the great Edinburgh results are not attainable by this method, unless conjoined with more ample and ready means for getting much larger quantities of sewage on a given area, in less time, and with less labour and expense than can be done with the hose.

17. That upon grass lands, for which the application is best adapted, these larger quantities of the liquid sewage, deprived of its grosser particles, may be economically distributed, especially upon the lower levels, by a combination of the underground pipe system with the subsidiary open irrigation by small contour gutters, practised by Mr. Bickford.

18. That this work, being of a commercial or speculative nature, and not so much required for the safety of the public health, would fall rather within the province of local companies or proprietors than of the local authorities, and to those parties all facilities should be granted for carrying it out.

19. That the solid sewage manure, prepared and deodorized as above proposed, may be anywhere used, and any quantity of the liquid applied on absorbent or properly drained land, without any risk of injury to health, and without any of the offensiveness constantly experienced from farmyard and other solid manures applied as top dressings.

20. That in any neighbourhoods, however, where no opportunity exists for this beneficial irrigation, the liquid sewage, before being discharged into rivers or streams, should, after separation of the solid matter, be treated with lime or other deodorizing and precipitating agents; a duty which should devolve upon the Local Board or other governing body, as a precaution in which the public health is materially concerned.

Lastly, that it is an object of immense public concern that the poisonous accumulations of our towns, now fast becoming the sources of pollution of our rivers and streams, should without delay be rendered powerless for further mischief, and applied as nature's law demands for reproductive uses. That by this means the greatest sanitary problem will be solved, and the greatest advancement of agricultural prosperity secured.

In drawing this report to a close, I venture to express a hope that the attention I have been enabled to give to the subject may have added some little to our information; but impressed with its great importance

and its difficulties, extending as it does into so many branches of inquiry, I feel strongly my own inability to do justice to it. It is a subject of study not for engineers alone, but for agriculturists, physiologists, and chemists of the highest attainments and experience.

I have, &c.
HENRY AUSTIN,
Chief Superintending Inspector.

Whitehall, March 1857.

CONCLUSIONS from the FIRST and SECOND REPORTS of the SELECT COMMITTEE on the SEWAGE of TOWNS. Dated 10th April 1862.

Analysis of Evidence.

1. The evidence proves that sewage contains the elements of every crop which is grown.
2. That as compared with solid manure there are advantages in the application of sewage manure to land.
3. The evidence proves that town sewage contains a large amount of heat, which in itself is beneficial in stimulating vegetation.
4. The evidence also proves that the water alone of sewage is of great benefit for agricultural purposes.
5. The evidence further proves that one ton (224 gallons) of average town sewage contains an amount of manure which, if extracted and dried, would be worth a little over 2*d.*, taking Peruvian guano (at 11*l.* per ton) as the standard.
6. A judicious use of town sewage permanently improves land.
7. Sewage may be applied to common grass, Italian rye-grass, and also to roots and grain crops, with great advantage, dressings with sewage hastening vegetation.
8. Sewage-grown grass has a great effect in increasing the quantity and richness of the milk of cows, as well as improving the condition of the cattle, which prefer sewaged grass to all others.
9. The earth possesses the power of absorbing from sewage all the manure which it contains, if the dressings in volume are proportioned to the depth and quality of the soil.
10. Those who use sewage should have full control over it, that they may apply it when and in what quantities they may require it.
11. Heavy dressings of sewage (8,000 to 9,000 tons per acre) are wasteful; less dressings (500 to 2,000 tons per acre) when more carefully applied, produce better results. The enormous dressings recommended by some witnesses would be agriculturally useless, as the sewage would flow over and off the surface unchanged.
12. When the sewage of our cities, towns, and villages is utilized to the best advantage over suitable areas, little or no imported or manufactured manures would be required in such districts.
13. Sewage may be applied with advantage to every description of soil which is naturally or artificially drained.
14. The most profitable returns, as in the case of all other manures, will be obtained when sewage is judiciously applied to the best class of soils.
15. Sewage may be advantageously applied to land throughout the entire year.
16. Some matters used in manufactures which enter town sewers,

such as waste acids, would be in themselves injurious if applied to vegetation; but bearing as they do so small a proportion to the entire volume of sewage into which they are turned, they are rendered harmless.

17. Fresh sewage at the outfall of the sewers, even in the hottest weather, is very slightly offensive; and if applied to the land in this state, in such dressings as can at once be absorbed by the earth, fear of nuisance need not be felt, as the soil possesses the power to deodorize and separate from liquids all the manure which they contain.

18. Large dressings and an over-taxed soil may pollute surface streams, subsoils, and shallow wells.

19. Solid manure cannot be manufactured from town sewage with commercially profitable results.

Report on the Results of the Society of Arts Conference on Health and Sewage of Towns, June 1876.

Conclusions.

The chairman of the Conference and the Executive Committee, after having carefully considered the information furnished from the various localities as well as the facts brought forward during the Conference, have to submit the following as the conclusions to which such information appears to lead:—

1. In certain localities where land at a reasonable price can be procured with favourable natural gradients, with soil of a suitable quality and in sufficient quantity, a sewage farm, if properly conducted, is apparently the best method of disposing of water-carried sewage. It is essential, however, to bear in mind that a profit should not be looked for by the locality establishing the sewage farm, and only a moderate one by the farmer.
2. With regard to the various processes based upon subsidence, precipitation, or filtration, it is evident that by some of them a sufficiently purified effluent can be produced for discharge without injurious result into water-courses and rivers of sufficient magnitude for its considerable dilution; and that for many towns where land is not readily obtained at a moderate price those particular processes afford the most suitable means of disposing of water-carried sewage. It appears, further, that the sludge, in a manurial point of view, is of low and uncertain commercial value, that the cost of its conversion into a valuable manure will preclude the attainment of any adequate return on the outlay and working expenses connected therewith, and that means must therefore be used for getting rid of it without reference to possible profit.
3. In towns where a water-carried system is employed, a rapid flow, thorough ventilation, a proper connexion of the house drains and pipes with the sewers, and their arrangement and maintenance in an efficient condition, are absolutely essential as regards health; hitherto sufficient precautions have rarely been taken for efficiently ensuring all the foregoing conditions.
4. With regard to the various dry systems where collection at short intervals is properly carried out, the result appears to be satisfactory, but no really profitable application of any one of them appears as yet to have been accomplished.
5. The old midden or privy system, in populous districts, should be discontinued, and prohibited by law.

6. Sufficient information was not brought forward at the Conference to enable the Committee to express an opinion in regard to any of the foreign systems.
7. It was conclusively shown that no one system for disposing of sewage could be adopted for universal use; that different localities require different methods to suit their special peculiarities, and also that, as a rule, no profit can be derived at present from sewage utilization.
8. For health's sake, without consideration of commercial profit, sewage and excreta must be got rid of at any cost.

The Executive Committee, whilst abstaining from submitting any extensive measures, have no hesitation in recommending that the prevention of dangerous effects from sewage gases should receive the immediate attention of the Legislature, and they submit the following resolutions as the basis of petitions to Parliament :—

1. That the protection of public health from typhoid and other diseases demands that an amending Act of Parliament be passed, as soon as possible, to secure that all house drains connected with public sewers in the metropolis and towns having an urban authority should be placed under the inspection and control of local sanitary authorities, who shall be bound to see to the effective construction and due maintenance of all such house drains, pipes, and connexions. Provisions having this object in view already exist in the Act constituting the Commissioners of Sewers in the City of London, in the Metropolis Local Management Act, 1855, and in the Public Health Act, 1875, but practically they seem scarcely sufficient for the purpose.
2. That plans of such drains and connexions be deposited in the charge of the respective local authorities, who shall be bound to exhibit them and supply copies of them to the public on payment of a moderate fee.
3. That the owners of houses be compelled by law to send to the respective local authorities, within a specified time after the passing of the Act, plans of all house drains on an appointed scale.

Signed by—

Members of the Executive Committee.

- The Right Hon. James Stanfield, M.P., Chairman of the Conference.
- Lord Alfred S. Churchill, Chairman of the Council.
- F. A. Abel, F.R.S., President of the Chemical Society.
- Sir Henry Cole, K.C.B.
- Capt. Douglas Galton, R.E., C.B., F.R.S.
- Lieut.-Colonel E. F. Du-Cane, R.E. C.B., Surveyor General of Prisons.

LONDON:
Printed by George E. Eyre and William Spottiswoode,
Printers to the Queen's most Excellent Majesty.
For Her Majesty's Stationery Office.

BEDFORD SEWAGE FARM.

— SCALE OF FEET.

N B. *The red lines shew the surface carriers. Cast-iron mains from the sewage pumps are shewn by blue lines. The entire farm is free soil the small volume of outflow of water is at all times bright and pure.*

Plan

OF THE

DONCASTER SEWAGE FARM

IN

LONG SANDALL

in the West Riding of the

COUNTY OF YORK.

Key Plan shewing the situation of the Sewage Farm with reference to the Town of Doncaster

NOTE. The Main Sewers are shewn Red.

NOTE. The Sewage Carriers are shewn in Red and are Glazed Socket Pipes
The Subsoil Drains are shewn Blue and the — indicate the fall
The Levels given are height above mean sea level
The word 'Outlet' means Outlet from Sewage carriers for irrigation.

PLAN OF THE BARNHURST.
OR
WOLVERHAMPTON SEWAGE FARM.

STAFFORDSHIRE & WORCESTERSHIRE CANAL
BIRMINGHAM AND LIVERPOOL CANAL
Brook
Outlet
Outlet
From Pendeford
THE BARNHURST
GREAT WESTERN RAILWAY
LITTLE BARNHURST
From Shrewsbury
From Wolverhampton
NB Land drains shewn by blue lines
Pipes for conveying sewage to the upper land shewn by green lines.
Reservoirs coloured pink and numbered 1 2 are low areas, deep drained, to act as Land-Filters for storm-waters during heavy rain.
Scale 6 Chains to an Inch.

No. 4

TUNBRIDGE WELLS.

PLAN OF NORTHERN SEWAGE FARM

SHOWING

LINES OF MAIN AND SUBSIDIARY CARRIERS

DRAINS AND OTHER WORKS.

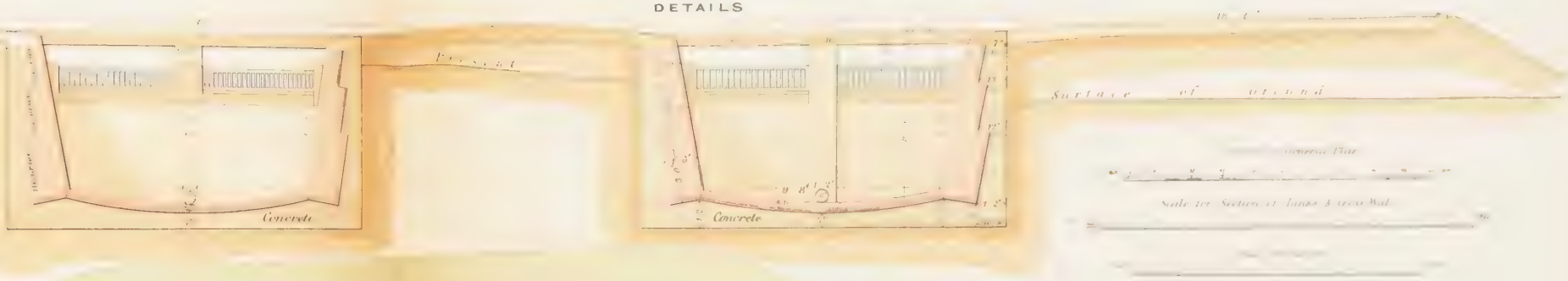
TUNBRIDGE WELLS SEWAGE UTILIZATION.

SETTLING TANKS IN NORTHERN VALLEY.

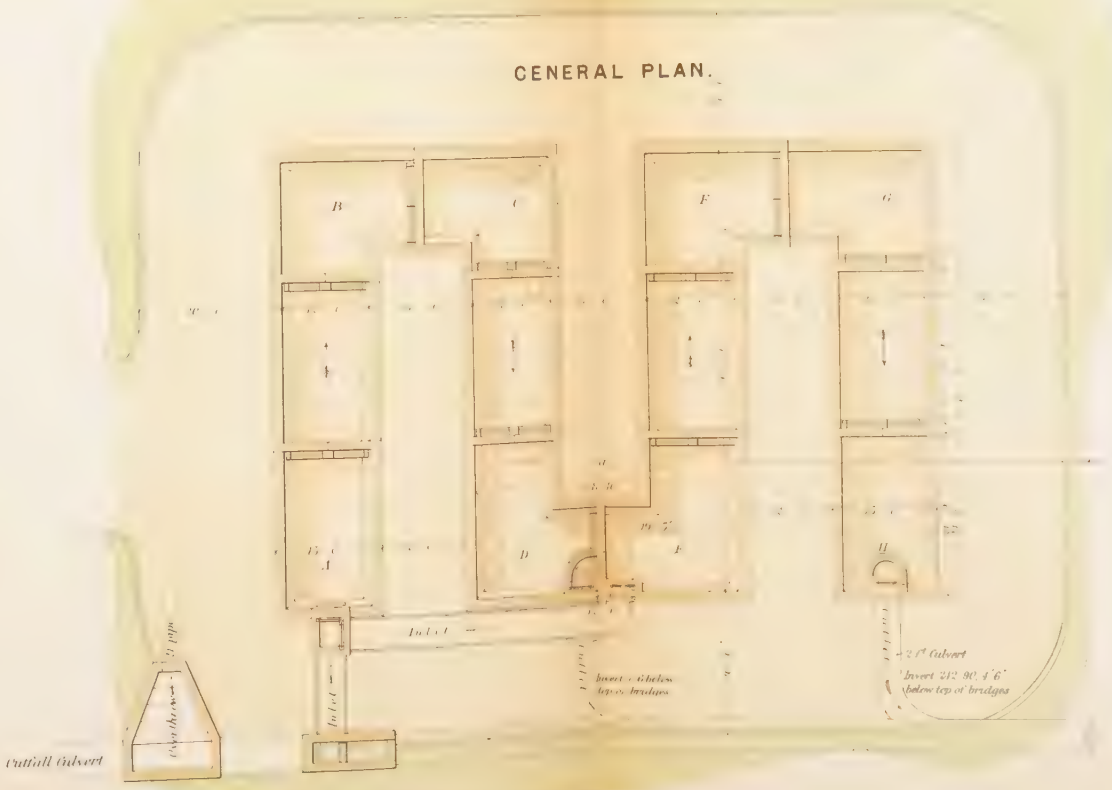
No. 5.

HALF SECTION OF TANKS A.A.

DETAILS



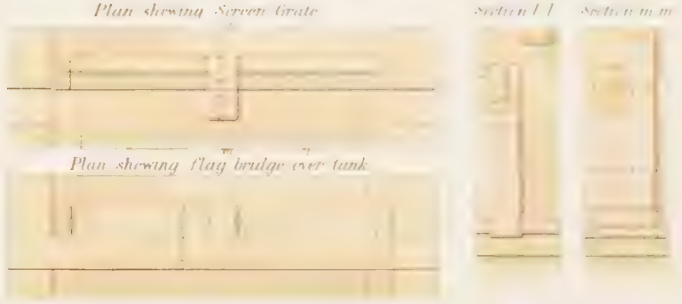
GENERAL PLAN.



Depth of Excavation

at	*A*	8 feet
	B	8 1½
	C	8 2
	D	8 3½
	E	8 4
	F	8 5½
	G	8 6
	H	8 4

CROSS WALL.



3FT SLUICE.

2FT SLUICE

TUNBRIDGE WELLS.

PLAN OF SOUTHERN SEWAGE FARM

SHOWING

LINES OF MAIN AND SUBSIDIARY CARRIERS

DRAINS AND OTHER WORKS.

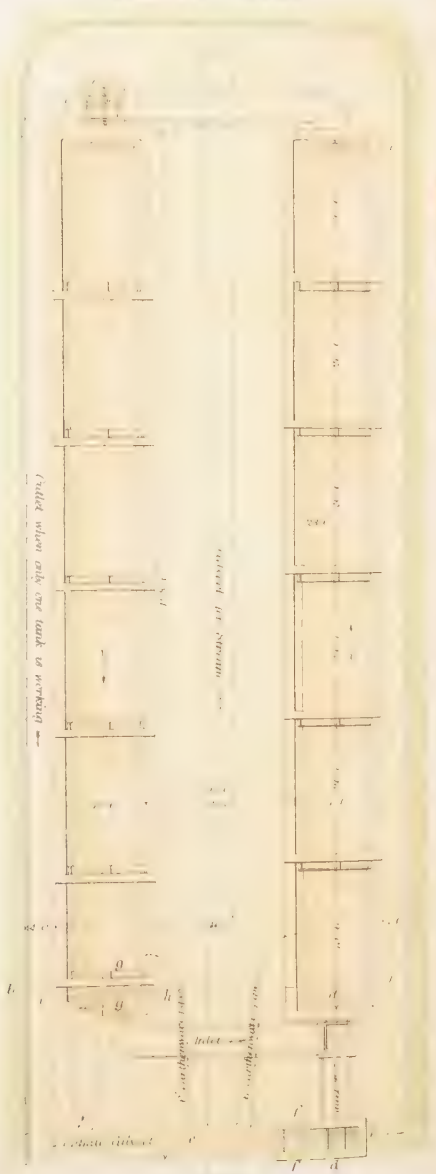
REFERENCE.

SCALE

TUNBRIDGE WELLS SEWAGE UTILIZATION.

SETTLING TANKS IN SOUTHERN VALLEY.

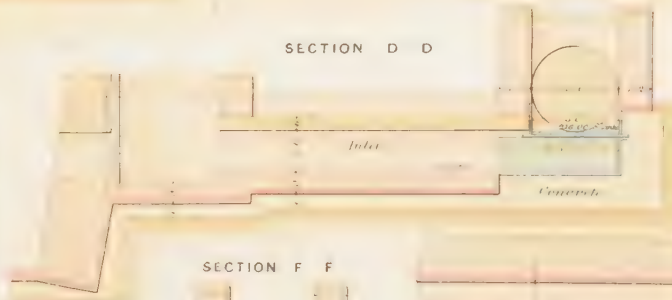
GENERAL PLAN.



SECTION B. B.

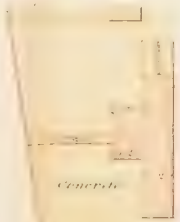
SECTION C. C.

SECTION D D

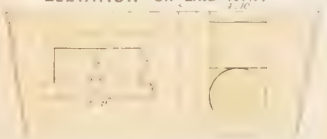


SECTION E. E. OVERFLOW CHAMBER.

SECTION G G.



ELEVATION ON LINE H. I.



SECTION F F

PLAN OF OVERFLOW CHAMBER.

Scale for Detail

No. 8.

LOCAL BOARD OF WEST DERBY.

SEWAGE FARM, FAZAKERLEY.

PLAN

SHEWING PLOTS AND CARRIERS.

NOTE.

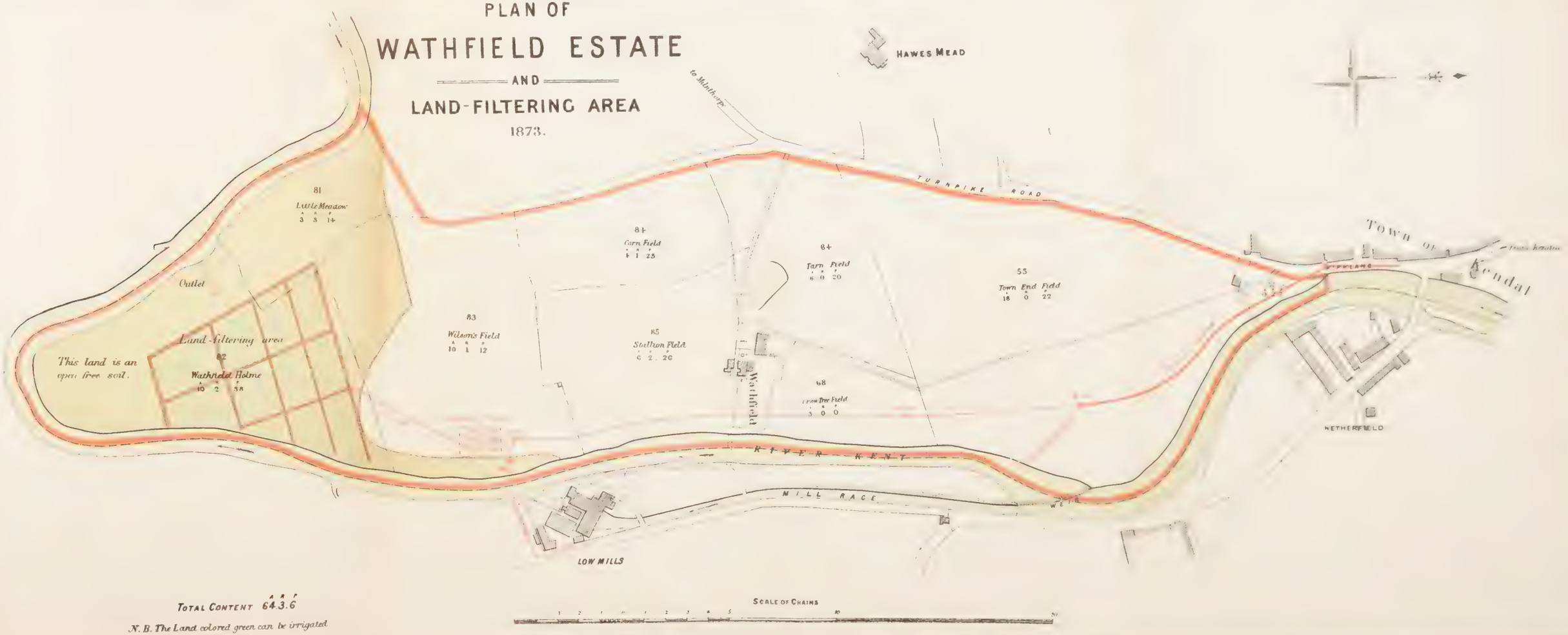
Carriers shewn in Blue Lines
Roads on Farm colored Red "
Main Roads colored Brown

REFERENCE.

PLOTS.	CONTENTS.	PLOTS	CONTENTS
A	9 81 Acres	L	19 37 Acres
B	7 04 "	M	4 22 "
C	5 95 "	N	4 95 "
D	16 64 "	O	11 57 "
E	7 41	P	9 52 "
F	7 67 "	Q	10 80 "
G	9 90 "	R	8 48 "
H	9 46 "	S	6 46 "
J	13 54 "	T	5 74 "
K	7 02 "	V	15 07 "
[illegible]	70 "	Cottage &c.	58in Plot E
Willows	2 51 "	"	67 " N
Plumb Tree	24 "	"	30 " V

N° 9.

PLAN OF
WATHFIELD ESTATE
AND
LAND-FILTERING AREA
1873.



TOTAL CONTENT 64.3.6

N. B. The Land colored green can be irrigated by gravitation
The estate is bounded by the strong red line

SCALE OF CHAINS

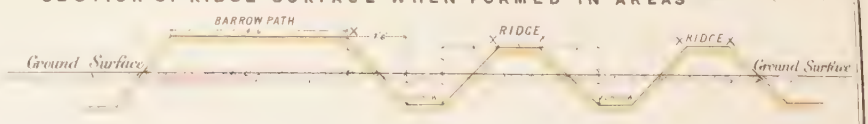
KENDAL SEWAGE

PLAN OF FILTERATION AREAS SHOWING THE CART ROAD & BARROW PATHS
WITH MAIN DELIVERY & BRANCH CONDUITS & DISTRIBUTING CARRIERS.

N° 10

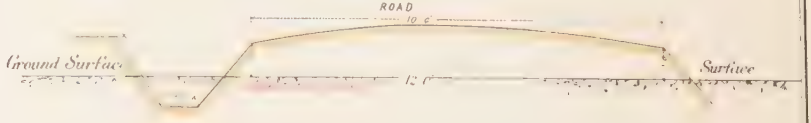
Sewage from the Town

SECTION OF RIDGE SURFACE WHEN FORMED IN AREAS

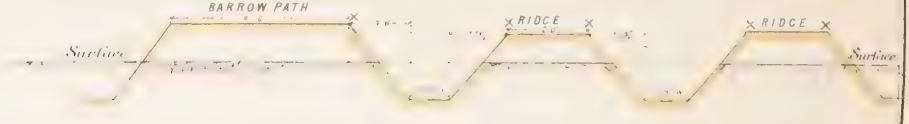


N.B. The ridges are cultivated at × along the side of each ridge.

SECTION



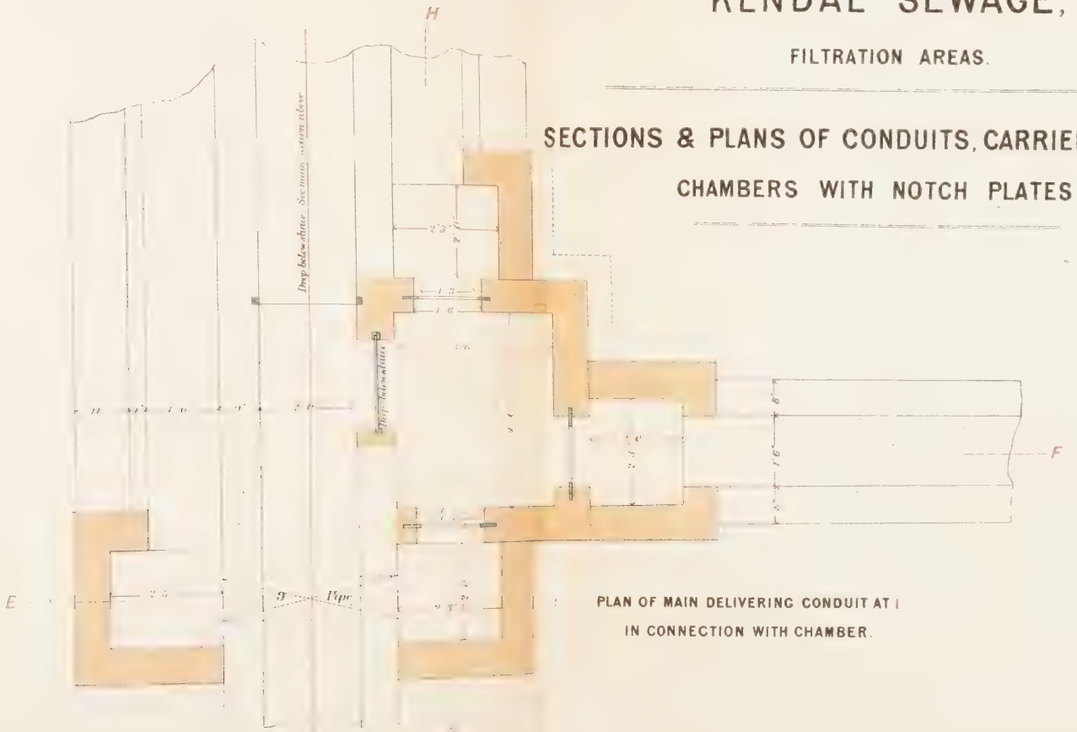
SECTION OF RIDGE SURFACE WHEN FORMED IN AREAS



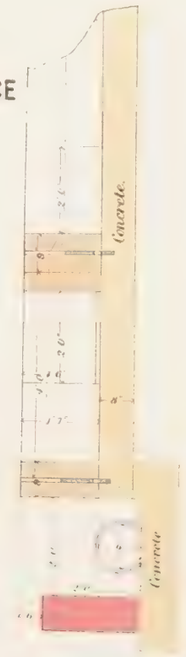
KENDAL SEWAGE,

FILTRATION AREAS.

SECTIONS & PLANS OF CONDUITS, CARRIERS & SLUICE CHAMBERS WITH NOTCH PLATES.



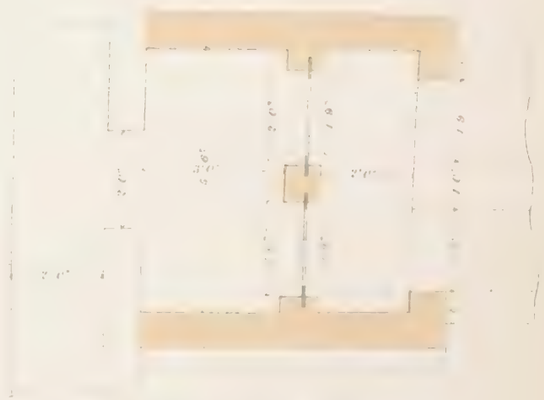
PLAN OF MAIN DELIVERING CONDUIT AT I
IN CONNECTION WITH CHAMBER.



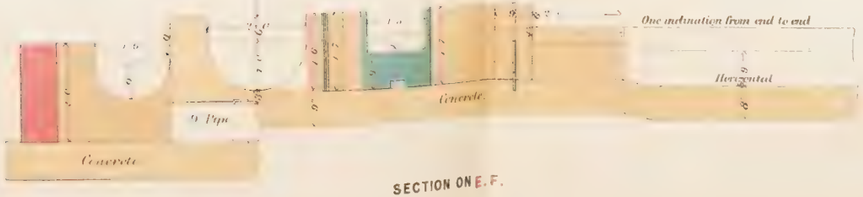
SECTION ON G.H.

NOTCH PLATES

		Notch above Width	Notch above Depth	Hole below Width	Hole below Depth
For Area	A	14¾	4"	2¾	2
. .	B	11¾	4	2¾	.
. .	C	.	.	.	.
. .	D	10	4"	4¾	2
. .	E	10	4	3¾	2
. .	F	10	4"	3¾	2
. .	G	18¾	4"	3¾	2"
. .	H	18¾	4"	3¾	2"
. .	I	6	4"	1¾	2"
. .	J	21	4"	4¾	2"
. .	K	24	4"	4¾	2"

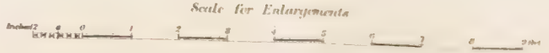


PLAN OF MAIN DELIVERING CONDUIT AT J
IN CONNECTION WITH CHAMBER



SECTION ON E.F.

Scale for Enlargements



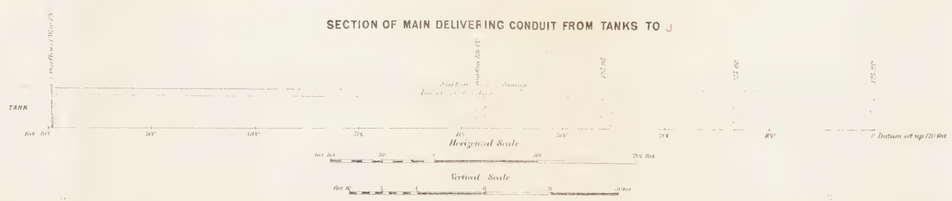
CROSS SECTION OF MAIN DELIVERING CONDUIT & CARRIERS.

KENDAL SEWAGE.

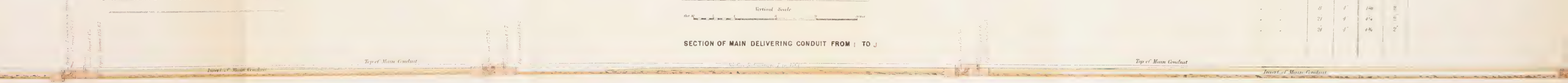
FILTRATION AREAS.

SECTIONS & PLANS OF CONDUITS, CARRIERS & SLUICE CHAMBERS WITH NOTCH PLATES.

SECTION OF MAIN DELIVERING CONDUIT FROM TANKS TO J



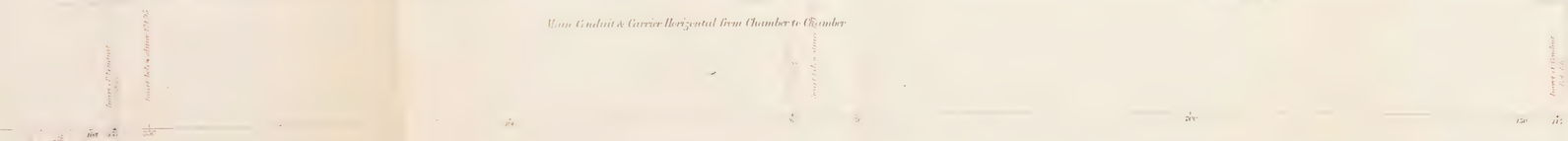
SECTION OF MAIN DELIVERING CONDUIT FROM I TO J



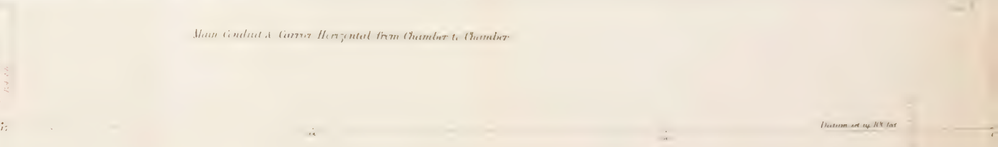
NOTCH PLATES

No.	Area	Vertical sluice Width	Vertical sluice Depth	Hole sluice Width	Hole sluice Depth
		14¾	4	2⅛	2
		14¾	4	2⅛	2
		10	4	3¼	2
		10	4	3¼	2
		10	4	3¼	2
		10	4	3¼	2
		18¼	4	2⅝	2
		18¼	4	2⅝	2
		6	4	1⅛	2
		24	4	4¼	2
		24	4	4¼	2

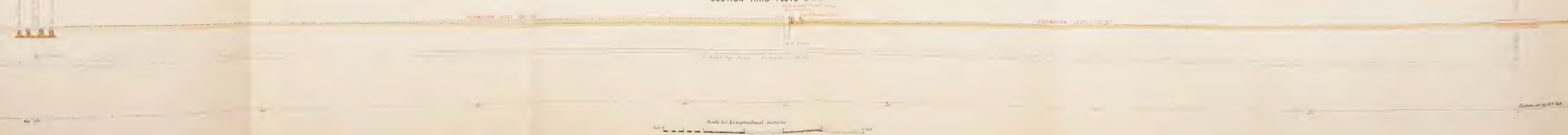
Main Conduit & Carrier Horizontal from Chamber to Chamber



Main Conduit & Carrier Horizontal from Chamber to Chamber



SECTION THRO PLOTS G H I



WIMBLEDON LOCAL BOARD

No 13

GENERAL PLAN.
OF
SEWAGE WORKS.

WIMBLEDON LOCAL BOARD

GENERAL PLAN

N.B. The lines in Blue are surface contours.
The lines in Red are sewage carriers.

PROPOSED CEMETERY

SCALE

PUBLIC HEALTH.

REPORTS

OF

THE MEDICAL OFFICER OF THE PRIVY COUNCIL AND LOCAL GOVERNMENT BOARD.

NEW SERIES, No. VII.

ANNUAL REPORT TO THE LOCAL GOVERNMENT BOARD WITH REGARD TO THE YEAR 1875.

Presented pursuant to Act of Parliament.

LONDON:
PRINTED BY GEORGE E. EYRE AND WILLIAM SPOTTISWOODE.
PRINTERS TO THE QUEEN'S MOST EXCELLENT MAJESTY.
FOR HER MAJESTY'S STATIONERY OFFICE.

1876.

[C.—1508.] *Price* 1*s.* 4*d.*

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REPORT.

TO THE RIGHT HON. GEORGE SCLATER-BOOTH, M.P.,
PRESIDENT OF THE LOCAL GOVERNMENT BOARD.

SIR,

MEDICAL OFFICER'S REPORT.

I HAVE the honour of submitting to you my Report of the proceedings which in the year 1875 you directed to be taken through the Medical Department of the Local Government Board in matters concerning the Public Health.

I. A large part of the proceedings consisted as previously, and as was explained at some length in my last year's Report, in the inspection of Public Vaccination, with other superintendence of the action of the local authorities and officers who are charged with duties under the Vaccination Acts.

1. Under the system which the Lords of the Council established, and which has been continued under the Local Government Board, each ordinary vaccination-district of England is visited by one of the Inspectors of this Department once in every two years*; but in the year 1874 (as I had to mention in my last year's Report) it had happened that this customary inspection was, from accidental causes, considerably interrupted; and as it was necessary in 1875 to deal with the arrears which had thus arisen, the quantity of vaccination-inspections done during 1875 was to that extent in excess of an average yearly amount. The inspections of the former year had extended only to 1,357 vaccination-districts, comprised in 275 Unions and non-united parishes; but those of 1875 extended to 1,782 vaccination-districts comprised in 371 unions and parishes. In Appendix No. 1 I enumerate the unions and parishes which were inspected as above, and give particulars as to the awards of money which were made in each case to the public vaccinators, under § 5 of the Vaccination Act of 1867, out of the grant provided by Parliament for this purpose. The awards actually made amounted to 15,676*l.*; but a portion of this amount, probably about 2,500*l.*, represented the accidental excess of the vaccination-inspections of 1875 beyond the average yearly number.

2. The success of our modern vaccination-laws in enforcing the general vaccination of infants is to be measured by the periodical returns which are made to the Board, under the Act of 1871, by the so-called vaccination-officers throughout the country. Of such returns the first collection, which related to children born in the

* A few districts are, for special reasons, visited every year.

year 1872, was completed early in 1874, and a digest of it, prepared by Dr. Seaton, was included in my last Annual Report: a second such collection, relating to children born in 1873, was completed early in 1875, and Dr. Seaton's digest of it is now given in Appendix No. 2. It will there be seen that of the 826,508 children registered as born in England and Wales in the year 1873, all, up to a margin of less than 5 per cent. had, at the time of closing the return, been accounted for by the vaccination-officers; that, of the 95⅔ per cent. accounted for, 85⅕ were accounted for as vaccinated, and 9¾ as having died early and unvaccinated; while the small residue, not quite ⅔ per cent. of the whole number of births, included infants who had contracted smallpox before they could be vaccinated, infants who had been certified as insusceptible of vaccination, and (as by far the largest item) infants whose vaccination had for the time been postponed under medical certificate.

3. The maintenance of the public supply of vaccine lymph, and the arrangements under which candidates for appointment as public vaccinators obtain the authorised certificates of proficiency in vaccination required of them by the regulations of the Board, were in 1875 as usual superintended by the Board through this Department; and the vaccination-stations which are concerned with those special objects underwent their usual special inspection. Subjoined, in Appendix No. 3, I give the statistics of these branches of service; and here I need only mention that in 1873 the Department supplied vaccine lymph in answer to more than 10,000 applications.

II. In 1875, 27 local inquiries were made by inspectors of this Department with regard to particular facts of disease in particular places, or to conditions which were deemed likely to cause disease; and I subjoin, in Appendix No. 4., a list of these inquiries, with an abstract of the chief results of each as reported by the medical inspector. In 4 of the 27 cases (Nos. 14, 15, 21, 23) the matter of inquiry lay chiefly or wholly outside the province of the local sanitary authority; but in the other 23 cases, the inspectors' reports, so far as they go, exhibit the working of the Sanitary Acts under the 41 local authorities (25 urban and 16 rural) whose districts were visited. In England and Wales, however, the areas of separate jurisdiction for general sanitary purposes are 1557; that is to say, in addition to the 39 which are metropolitan, there are 928 urban and 590 rural jurisdictions: and the above inspections, extending to only 41 of this number, though they represent, as applied to the new Local Sanitary Administration, the inquiring function which was formerly exercised by the Privy Council under the Act of 1858 in matters concerning the Public Health, evidently do not constitute an amount of observation on which it would be possible for me to base any such general report under that Act with regard to the sanitary progress and requirements of the country as I can present with regard to vaccination.

Concerning two of the cases in which local inquiry was made

the reports, which in both cases are by Dr. Buchanan, are subjoined in full. The one (Appendix No. 5.) relates to a considerable and very disappointing prevalence of enteric fever in the town of Croydon, where for many years great exertions have been made for sanitary improvement, and in regard of which it is therefore particularly important that the explanation of so unexpected a result should, if possible, be arrived at. The other (Appendix No. 6.) relates to a curious outbreak of scarlatina among certain persons—a private family and its guests, who had met on a festive occasion, and who, it seemed probable, might have got their infection in common from partaking of an infected article of food.

Places were also visited by medical inspectors on six occasions with reference to questions of hospital-accommodation for cases of infectious disease: chiefly in order to assist the Board in determining whether (under a provision of law which has since been repealed) it should declare particular hospitals to be for the purposes of the law within a "convenient distance" of particular sanitary districts, or whether its approval, required in other respects for the particular hospital-arrangements, should be given. On one of these occasions the question concerned the five small neighbouring urban districts of Drighlington, Birstal, Birkenshaw, Churwell, and Atherton; on another, the two neighbouring rural districts of Chester and Tarvin; on the others, singly, the respective rural districts of Darlington and Hexham, and the respective urban districts of Todmorden and Over.

III. In addition to the above proceedings, two general inquiries, of the sort by which the Board from time to time seeks to increase its own knowledge and efficiency with regard to particular sections of the large sphere of medical subject-matter in which it has to advise or direct, were, in 1875, begun in the Medical Department:—one, a more exact and systematic study of the conditions which determine the spread and intensity of scarlatina; the other, a study concerning the effluvium-nuisances which arise in connexion with various manufacturing and other branches of industry, and specially with regard to the effect upon health of each such industry, and to the degree in which the nuisance can be prevented.

1. The inquiry concerning scarlatina is in the hands of Dr. Buchanan, who, by way of introduction to it, has had to make careful examination of the mortuary statistics of the disease as presented in the Registrar-General's returns of the last 22 years. This examination has not hitherto suggested any clue which could advantageously be followed up by detailed local inquiries; and it seems probable that the progress of the investigation must mainly depend on opportunities which the Department may accidentally find, or which the friendly co-operation of local officers of health and of private medical practitioners may afford us, for studying in detail, and at the earliest possible moment, such outbreaks of scarlatina as shall appear exceptional in any of their circum-

stances, and particularly those where the outbreak may seem imputable to any other cause than contagion.

2. The inquiry concerning the branches of industry which tend to produce nuisance by their effluvia is in the hands of Dr. Ballard, who possesses very eminent qualifications for dealing with it successfully. Inspections in contribution to it have already been made by him on a large scale in and about the Metropolis and down the Thames, as also at several centres of industry in the Midland Black Country and in Lancashire, and at Plymouth and Devonport, Bristol, Southampton, and some other places: and the offensive industries, large and small, which he has investigated, are already not fewer than fifty. Extension of the inquiry is still necessary, especially in order that the practical conclusions arrived at, with regard to the degree in which any given effluvium-nuisance is preventable, may rest on a sufficiently large basis of facts; and I therefore, instead of now bringing before you any fragmentary statement from Dr. Ballard, propose that his whole treatment of the subject should come before you later in a supplement to the present Report.

IV. In respect of the cognizance which the Medical Department has to take of the progress of Foreign Epidemics I subjoin (Appendix No. 7.) a Memorandum by Mr. Netten Radcliffe on the modern history and more recent movements of Levantine Plague. I regret to observe that at the present time the infection of the disease is in Baghdad; for, being there, it may find considerable facilities for diffusing itself to other places; and though, in view of the experience of the last two centuries, we need not, I think, anticipate as probable, that, if plague should extend considerably in the Levant, it must therefore necessarily extend to any part of Western Europe, still, any wide Eastern diffusion of the disease, especially if to the seaports of Turkey or Egypt, could hardly fail to excite alarm in Western Europe, and at least to cause much derangement of traffic.

In my last Annual Report I mentioned that Mr. Radcliffe was at the time engaged in compiling an account of the movements of Asiatic Cholera, in relation to Europe for the last preceding ten years; and subsequently, in supplement to the Annual Report, I had the honour of submitting to you the elaborate compilation which Mr. Radcliffe with some months further work had then completed. Since the date of that supplementary report of last year, nothing in respect of cholera has occurred which seems to require present mention.

I am, sir,
Your obedient servant,
John Simon.

Medical Department, March 31, 1876.

APPENDIX.

No. 1.

List (alphabetically arranged) of 371 Unions inspected during the Year 1875, with reference to their Proceedings under the Vaccination Acts, 1867 and 1871, and an Account of the Awards made to the respective Public Vaccinators out of Moneys voted by Parliament for that Purpose.

Union.	No. of Vaccination Districts in Union.	No. of respective Vaccination Contractors recommended for Award.		Range of Awards in each Union.		Total Sum awarded in the Union.	Name of Inspector.
		1st Class Award.	2nd Class Award.	Minimum.	Maximum.		
				£ s. d.	£ s. d.	£ s. d.	
Aberayron	2	1	1	8 4 8	13 9 0	21 13 8	Dr. Airy.
Aberystwith	5	1	3	7 5 4	15 0 0	42 13 4	Do.
Alcester	5	1	—	—	—	3 11 0	„ Ballard.
Alderbury	5	4	—	4 7 0	24 18 0	41 19 0	„ Blaxall.
Amersham	7	2	1	6 9 4	10 10 0	23 19 4	„ Thorne.
Amesbury	2	1	1	5 17 0	6 0 0	11 17 0	„ Blaxall.
Anglesey	3	1	—	—	—	8 15 0	Do.
Asaph, St.	5	1	—	—	—	5 4 0	Do.
Ashford, East	6	3	—	2 0 0	7 0 0	11 15 0	„ Stevens.
Ashford, West	3	3	—	5 14 0	18 4 0	33 5 0	Do.
Ashton-under-Lyne	12	6	—	8 12 0	42 10 0	152 5 0	„ Beard.
Aston	7	3	—	8 11 0	88 1 0	160 3 0	Mr. Power.
Atcham	6	—	—	—	—	—	Dr. Blaxall.
Atherstone	2	—	—	—	—	—	Mr. Power.
Auckland	9	6	—	18 10 0	50 14 0	193 9 0	Do.
Axbridge	12	3	1	2 9 0	7 13 0	16 19 8	Dr. Blaxall.
Aylesbury	7	5	—	5 14 0	13 17 0	40 10 0	„ Thorne.
Aysgarth	3	1	—	—	—	2 18 0	Mr. Power.
Bala	1	—	—	—	—	—	Dr. Blaxall.
Banbury	7	3	2	3 0 8	7 8 0	23 12 0	„ Thorne.
Bangor and Beaumaris.	5	—	—	—	—	—	„ Blaxall.
Barnsley	6	4	—	2 12 0	66 4 0	111 8 0	„ Beard.
Barton-on-Irwell	5	4	—	9 12 0	44 14 0	90 5 0	Do.
Bath	5	3	1	2 8 0	45 6 0	60 9 0	„ Blaxall.
Battle	6	1	—	—	—	2 5 0	„ Stevens.
Beaminster	5	—	—	—	—	—	„ Blaxall.
Bedale	3	3	—	2 13 0	9 18 0	17 0 0	Mr. Power.
Bedminster	9	4	—	3 15 0	10 0 0	27 14 0	Dr. Blaxall.
Belford	2	—	2	2 8 0	3 6 0	5 14 0	Mr. Power.
Berwick	5	3	—	1 6 0	16 2 0	24 14 0	Do.
Bethnal Green	2	2	—	61 19 0	120 6 0	182 5 0	Dr. Stevens.
Bicester	7	1	1	3 16 0	5 15 0	9 11 0	„ Thorne.
Billericay	5	—	1	—	—	3 14 0	„ Airy.
Birmingham	1	1	—	—	—	275 14 0	„ Seaton.
Blackburn	10	6	—	23 10 0	39 5 0	185 1 0	„ Beard.
Blandford	4	—	1	—	—	3 16 0	„ Blaxall.
Blean	4	2	—	11 18 0	15 0 0	26 18 0	„ Stevens.
Blything	8	2	—	5 7 0	6 12 0	11 19 0	„ Airy.
Bolton	8	6	—	6 10 0	95 3 0	210 11 0	„ Beard.
Bosmere and Claydon	5	2	1	3 18 0	6 1 0	15 16 0	„ Airy.
Brackley	5	2	—	4 5 0	6 7 0	10 12 0	„ Thorne.
Bradford (Wilts)	3	—	1	—	—	1 18 0	„ Blaxall.
Bradford (Yorks.)	6	3	—	24 6 0	50 8 0	107 0 0	„ Beard.
Braintree	4	4	—	8 2 0	21 8 0	57 14 0	„ Airy.
Bramley	5	3	—	4 12 0	32 11 0	46 5 0	„ Beard.
Brecknock	3	2	—	10 18 0	12 1 0	22 19 0	„ Airy.
Brentford	9	2	2	7 3 4	18 1 0	43 17 8	„ Thorne.
Bridge	5	4	—	2 4 0	7 0 0	20 4 0	„ Stevens.
Bridgend and Cowbridge.	4	1	—	—	—	27 9 0	„ Airy.

App. No. 1.

Inspection of Public Vaccination.

Union.	No. of Vaccination Districts in Union.	No. of respective Vaccination Contractors recommended for Award.		Range of Awards in each Union.		Total Sum awarded in the Union.	Name of Inspector.
		1st Class Award.	2nd Class Award	Minimum.	Maximum.		
				£ s. d.	£ s. d.	£ s. d.	
Bridgewater	10	1	2	1 16 0	7 12 0	15 2 0	Dr. Blaxall.
Bridgnorth	3	2	—	6 18 0	11 19 0	18 17 0	Do.
Bridport	4	2	—	4 16 0	5 10 0	10 6 0	Do.
Brighton	2	1	1	19 6 8	37 2 0	56 8 8	„ Stevens.
Brixworth	6	2	1	3 4 0	5 12 0	12 2 8	„ Thorne.
Bromley	4	1	1	2 16 0	4 16 0	7 12 0	„ Stevens.
Buckingham	4	—	—	—	—	—	„ Thorne.
Builth	1	—	—	—	—	—	„ Airy.
Burnley	7	3	—	1 11 0	17 14 0	25 16 0	„ Beard.
Burton-on-Trent	8	1	—	—	—	21 7 0	„ Ballard.
Bury	6	4	—	19 2 0	32 17 0	109 6 0	„ Beard.
Calne	1	—	—	—	—	—	„ Blaxall.
Camberwell	5	5	—	3 11 0	39 18 0	117 9 0	„ Stevens.
Cambridge	1	—	—	—	—	—	Mr. Power.
Canterbury	1	1	—	—	—	20 15 0	Dr. Stevens.
Cardiff	6	3	1	2 8 0	56 17 0	113 6 8	„ Airy.
Cardigan	3	1	—	—	—	12 14 0	Do.
Carmarthen	8	2	1	2 8 8	14 19 0	30 16 8	Do.
Carnarvon	5	—	—	—	—	—	„ Blaxall.
Castle Ward	6	2	—	4 5 0	11 13 0	15 18 0	Mr. Power.
Caxton and Arrington	5	3	—	9 16 0	13 11 0	35 13 0	Do.
Cerne	4	1	1	0 12 8	5 15 0	6 7 8	Dr. Blaxall.
Chailey	4	1	—	—	—	9 9 0	„ Stevens.
Chard	7	1	—	—	—	10 12 0	„ Blaxall.
Cheadle	5	2	2	3 1 4	11 14 0	28 15 4	„ Ballard.
Chelmsford	10	6	1	2 7 4	14 7 0	57 4 4	„ Airy.
Chelsea	2	2	—	12 6 0	93 16 0	106 2 0	„ Stevens.
Chester-le-Street	2	2	—	46 5 0	77 6 0	123 11 0	Mr. Power.
Chesterton	7	2	—	12 19 0	13 13 0	26 12 0	Do.
Chichester	1	1	—	—	—	8 1 0	Dr. Stevens.
Chippenham	7	1	1	3 2 0	4 8 0	7 10 0	„ Blaxall.
Chipping Norton	4	1	2	2 10 0	11 8 0	24 7 0	„ Thorne.
Chorley	5	2	—	17 12 0	19 1 0	36 13 0	„ Beard.
Chorlton	11	3	1	2 15 4	47 16 0	88 18 4	Do.
Church Stretton	4	1	—	—	—	4 0 0	„ Blaxall.
Cleobury Mortimer	2	—	—	—	—	—	Do.
Clitheroe	5	1	—	—	—	4 8 0	„ Beard.
Clun	4	—	1	—	—	2 0 8	„ Blaxall.
Clutton	5	2	—	2 6 0	19 19 0	22 5 0	Do.
Colchester	1	1	—	—	—	39 11 0	„ Airy,
Conway	2	2	—	14 3 0	20 1 0	34 4 0	„ Blaxall.
Corwen	3	—	—	—	—	—	Do.
Cosford	6	3	—	5 17 0	12 5 0	25 5 0	„ Airy.
Cranbrook	6	3	—	1 18 0	8 0 0	17 4 0	„ Stevens.
Crickhowel	2	Under consideration.					„ Airy.
Cricklade and Wootton Bassett.	3	—	1	—	—	4 19 4	„ Blaxall.
Cuckfield	6	5	—	2 6 0	9 3 0	35 15 0	„ Stevens.
Darlington	5	1	—	—	—	57 3 0	Mr. Power.
Dartford	5	5	—	11 9 0	27 13 0	82 10 0	Dr. Stevens.
Daventry	6	1	1	2 17 4	8 4 0	11 1 4	„ Thorne.
Devizes	7	2	1	2 8 8	16 9 0	25 7 8	„ Blaxall.
Dewsbury	11	5	—	7 4 0	19 4 0	64 2 0	„ Beard.
Dolgelly	5	3	—	2 14 0	9 15 0	21 13 0	„ Blaxall.
Doncaster	7	3	—	4 5 0	15 3 0	24 6 0	„ Beard.
Dorchester	6	1	—	—	—	7 4 0	„ Blaxall.
Dover	4	1	1	3 15 4	6 3 0	9 18 4	„ Stevens.
Drayton	5	1	—	—	—	0 15 0	„ Blaxall.
Dulverton	3	—	1	—	—	0 14 0	Do.
Dunmow	6	—	—	—	—	—	„ Airy.
Durham	5	2	—	10 4 0	44 15 0	54 19 0	Mr. Power.
Easington	5	3	—	15 9 0	30 10 0	70 17 0	Do:
Easingwold	4	2	1	2 4 0	5 19 0	12 1 0	Do.
East Grinstead	5	3	1	5 17 0	9 1 4	30 10 4	Dr. Stevens.
East Preston	4	—	—	—	—	—	Do.
Eastbourne	4	4	—	2 17 0	26 6 0	36 15 0	Do.
Eastry	7	5	—	4 9 0	10 7 0	34 12 0	Do.
Eccleshall Bierlow	3	1	—	—	—	116 19 0	„ Beard.
Edmonton	13	7	1	0 10 8	33 2 0	86 11 8	„ Thorne.
Elham	5	1	—	—	—	5 0 0	„ Stevens.
Ellesmere	7	1	—	—	—	2 7 0	„ Blaxall.

Union.	No. of Districts in Union.	No. of respective Vaccination Contractors recommended for Award.		Range of Award in each Union.		Total Sum awarded in the Union.	Name of Inspector.
	Vaccination	1st Class Award.	2nd Class Award.	Minimum.	Maximum.		
				£ s. d.	£ s. d.	£ s. d.	
Ely	7	2	—	11 7 0	13 19 0	25 6 0	Mr. Power.
Epping	10	—	—	—	—	—	Dr. Airy.
Eton	8	2	—	8 11 0	11 11 0	20 2 0	„ Thorne.
Faversham	4	3	—	12 10 0	13 3 0	38 13 0	„ Stevens.
Festiniog	3	—	—	—	—	—	„ Blaxall.
Foleshill	5	1	—	—	—	13 4 0	Mr. Power.
Forden	4	1	—	—	—	8 6 0	Dr. Blaxall.
Frome	5	—	—	—	—	—	Do.
Fylde, The	5	—	—	5 12 0	15 13 0	39 3 0	„ Beard.
Garstang	3	2	—	7 2 0	11 4 0	18 6 0	Do.
Gateshead	6	—	—	—	—	—	Mr. Power.
George St., East	1	1	—	—	—	72 17 0	Dr. Stevens.
Goole	5	Under consideration.				—	„ Beard.
Gower	2	1	—	—	—	9 13 0	„ Airy.
Gravesend and Milton	1	1	—	—	—	16 1 0	„ Stevens.
Guisborough	6	1	—	—	—	9 10 0	Mr. Power.
Hackney	4	4	—	9 3 0	30 8 0	77 17 0	Dr. Stevens.
Hailsham	6	3	—	3 16 0	7 4 0	15 13 0	„ Do.
Halifax	9	5	—	13 12 0	27 10 0	111 10 0	„ Beard.
Halstead	5	1	—	—	—	3 5 0	„ Airy.
Hardingstone	3	2	—	6 10 0	9 19 0	16 9 0	„ Thorne.
Hartismere	5	—	—	—	—	—	„ Airy.
Hartlepool	3	2	1	1 15 4	52 14 0	99 15 4	Mr. Power.
Hastingden	6	4	—	5 5 0	26 8 0	66 18 0	Dr. Beard.
Hastings	2	2	—	1 16 0	32 0 0	33 16 0	„ Stevens.
Harverfordwest	4	1	—	—	—	12 16 0	„ Airy.
Hawarden	3	2	—	18 15 0	19 5 0	38 0 0	„ Blaxall.
Hay	3	2	—	6 14 0	9 10 0	16 4 0	„ Airy.
Headington	2	—	1	—	—	27 3 4	„ Thorne.
Helmsley Blackmoor	2	2	—	4 7 0	4 16 0	9 3 0	Mr. Power.
Hemsworth	4	3	—	1 11 0	9 0 0	17 18 0	Dr. Beard.
Hendon	7	2	—	3 19 0	12 15 0	16 14 0	„ Thorne.
Henley	6	2	—	8 19 0	9 16 0	18 15 0	Do.
Highworth and Swindon.	4	—	—	—	—	—	„ Blaxall.
Holbeck	1	—	—	—	—	—	„ Beard.
Hollingbourne	6	3	—	3 2 0	8 14 0	19 7 0	„ Stevens.
Holyhead	3	—	—	—	—	—	„ Blaxall.
Holywell	5	2	—	25 8 0	28 2 0	53 10 0	Do.
Hoo	1	—	—	—	—	—	„ Stevens.
Horsham	6	4	1	1 3 4	15 1 0	33 12 4	Do.
Houghton-le-Spring	4	3	—	11 13 0	22 4 0	49 13 0	Mr. Power.
Hoxne	8	4	—	1 11 0	8 9 0	19 18 0	Dr. Airy.
Huddersfield	16	12	—	8 0 0	38 16 0	225 8 0	„ Beard.
Hunslet	3	2	—	2 13 0	9 9 0	12 2 0	Do.
Ipswich	1	1	—	—	—	76 6 0	„ Airy.
Islington	4	4	—	37 14 0	50 6 0	171 16 0	„ Stevens.
Kettering	4	2	—	11 7 0	17 17 0	29 4 0	Dr. Thorne.
Keynsham	1	1	—	—	—	63 2 0	„ Blaxall.
Kirkby Moorside	1	1	—	—	—	9 0 0	Mr. Power.
Knaresborough	3	—	—	—	—	—	Dr. Beard.
Knighton	4	—	—	—	—	—	„ Airy.
Lambeth	5	5	—	15 14 0	81 3 0	236 16 0	„ Stevens.
Lampeter	2	—	2	2 1 4	5 1 4	7 2 8	„ Airy.
Lancaster	5	—	—	—	—	—	„ Beard.
Lanchester	4	—	—	—	—	—	Mr. Power.
Langport	6	—	—	—	—	—	Dr. Blaxall.
Leeds	7	5	—	2 4 0	112 1 0	307 15 0	„ Seaton.
Leek	5	1	—	—	—	8 0 0	„ Ballard.
Leigh	3	2	—	21 15 0	28 19 0	50 14 0	„ Beard.
Lewes	1	1	—	—	—	10 11 0	„ Stevens.
Lewisham	5	5	—	6 11 0	19 12 0	72 7 0	Do.
Lexden and Winstree	9	3	2	3 1 0	9 16 0	33 3 4	„ Airy.
Leyburn	6	1	—	—	—	1 16 0	Mr. Power.
Lichfield	6	3	—	3 12 0	29 2 0	42 11 0	Dr. Ballard.
Linton	3	1	—	—	—	12 13 0	Mr. Power.
Liverpool	3	3	—	100 8 0	210 0 0	486 7 0	Dr. Seaton.
Llandilo Faur	4	2	—	15 14 0	24 1 0	39 15 0	„ Airy.

App. No. 1.

Inspection of Public Vaccination.

Union.	No. of Vaccination Districts in Unions.	No. of respective Vaccination Contractors recommended for Award.		Range of Award in each Union.		Total Sum awarded in the Union.	Name of Inspector.
		1st Class Award.	2nd Class Award.	Minimum.	Maximum.		
				£ s. d.	£ s. d.	£ s. d.	
Llandovery	2	—	—	—	—	—	Dr. Airy.
Llanelly	2	—	—	—	—	—	Do.
Llanfyllin	5	—	—	—	—	—	„ Blaxall.
Llanrwst	2	—	—	—	—	—	Do.
London, city of	2	2	—	27 13 0	32 12 0	60 5 0	„ Stevens.
Ludlow	5	—	1	—	—	7 8 0	„ Blaxall.
Lunesdale	5	1	—	—	—	3 3 0	„ Beard.
Machynlleth	5	—	—	—	—	—	„ Blaxall.
Madeley	4	1	—	—	—	41 19 0	Do.
Maidstone	5	4	—	5 19 0	51 7 0	74 9 0	Dr. Steven.
Maldon	7	1	1	6 5 4	6 14 0	12 19 4	Dr. Airy.
Malling	4	3	—	10 6 0	15 6 0	37 3 0	„ Steven.
Malmesbury	4	1	1	5 10 8	9 2 0	14 12 8	„ Blaxall.
Malton	6	2	1	3 0 0	7 18 0	17 5 0	Mr. Power.
Manchester	3	3	—	109 2 0	131 17 0	367 7 0	Dr. Seaton.
Marlborough	2	1	—	—	—	5 6 0	„ Blaxall.
Marylebone	1	1	—	—	—	149 18 0	„ Steven.
Medway	3	2	—	26 13 0	43 1 0	69 14 0	Do.
Melksham	2	1	—	—	—	12 2 0	„ Blaxall.
Mere	2	2	—	7 19 0	9 15 0	17 14 0	Do.
Meriden	4	3	1	2 1 4	9 15 0	19 11 4	Mr. Power.
Merthyr Tydfil	9	7	—	7 6 0	76 3 0	348 15 0	Dr. Airy.
Midhurst	5	4	—	2 11 0	11 18 0	23 3 0	„ Stevens.
Mile End	2	2	—	36 19 0	57 0 0	93 19 0	Do.
Milton	2	2	—	14 9 0	34 16 0	49 5 0	Do.
Morpeth	8	—	—	—	—	—	Mr. Power.
Mutford and Lothingland.	3	—	2	13 13 4	20 4 8	33 18 0	Dr. Airy.
Narberth	4	—	—	—	—	—	„ Airy.
Neath	8	4	—	12 13 0	64 13 0	121 12 0	Do.
Neot's, St.	6	2	—	5 17 0	13 0 0	18 17 0	„ Stevens.
Newcastle-in-Emlyn	3	1	—	—	—	19 6 0	„ Airy.
Newcastle-under-Lyme.	3	1	—	—	—	41 4 0	„ Ballard.
Newcastle-on-Tyne	3	5	—	26 13 0	54 3 0	200 11 0	„ Seaton.
Newhaven	5	2	—	1 14 0	8 19 0	10 13 0	„ Stevens.
Newmarket	9	1	1	4 16 8	13 12 0	18 8 8	Mr. Power.
Newport (Salop)	4	1	—	—	—	4 17 0	Dr. Blaxall.
Newport Pagnell	11	1	—	—	—	4 10 0	„ Thorne.
Newtown and Llanidloes.	4	—	—	—	—	—	„ Blaxall.
Northallerton	4	1	—	—	—	1 16 0	Mr. Power.
Northampton	4	1	—	—	—	12 9 0	Dr. Thorne.
North Aylesford	2	2	—	23 2 0	23 7 0	46 9 0	„ Steven.
North Bierley	12	8	—	3 2 0	30 17 0	141 19 0	„ Beard.
North Witchford	4	2	—	5 2 0	7 14 0	12 16 0	Mr. Power.
Nuneaton	2	1	—	—	—	9 9 0	Do.
Oldham	6	3	—	13 1 0	62 8 0	98 19 0	Dr. Beard.
Ongar	6	—	—	—	—	—	„ Airy.
Ormskirk	6	1	2	2 18 8	4 14 0	10 13 4	„ Beard.
Orsett	6	3	—	2 10 0	11 17 0	22 5 0	„ Airy.
Oswestry	3	1	1	1 17 4	16 2 0	17 19 4	„ Blaxall.
Oundle	4	2	—	7 6 0	12 19 0	20 5 0	„ Thorne.
Ousebury, Great	6	5	—	2 8 0	8 16 0	19 11 0	„ Beard.
Oxford	1	1	—	—	—	42 17 0	„ Thorne.
Paddington	2	2	—	33 6 0	35 7 0	68 13 0	„ Steven.
Pancras, St.	1	1	—	—	—	258 14 0	Do.
Pateley Bridge	3	1	—	—	—	15 10 0	„ Beard.
Pembroke	6	4	—	7 4 0	19 8 0	44 14 0	„ Airy.
Penistone	3	2	—	11 1 0	17 16 0	28 17 0	„ Beard.
Penkridge	4	1	—	—	—	30 3 0	„ Ballard.
Peterborough	7	5	1	0 18 8	44 1 0	84 14 8	„ Thorne.
Petworth	4	4	—	2 13 0	10 8 0	19 8 0	„ Steven.
Pewsey	4	3	—	8 5 0	10 13 0	28 14 0	„ Blaxall.
Pickering	3	1	—	—	—	10 7 0	Mr. Power.
Plomesgate	6	2	1	4 12 0	5 2 8	14 14 8	Dr. Airy.
Pontardawe	2	—	—	—	—	—	Do.
Pontefract	7	3	1	3 4 8	38 15 0	62 9 8	„ Beard.
Pontypridd	8	4	—	10 6 0	35 6 0	96 8 0	„ Airy.
Poole	4	2	1	3 15 0	11 16 0	19 9 0	„ Blaxall.

Union.	No. of Vaccination Districts in Union.	No. of respective Vaccination Contractors recommended for Awards. 1st Class Award.	2nd Class Award.	Range of Award in each Union. Minimum. £ s. d.	Maximum. £ s. d.	Total Sum awarded in the Union. £ s. d.	Name of Inspector.
Potterspury	4	—	—	—	—	—	Dr. Thorne.
Prescot	8	4	—	6 17 0	53 15 0	101 14 0	„ Beard.
Prestcigne	1	1	—	—	—	8 8 0	„ Airy.
Preston	8	4	—	18 0 0	28 13 0	90 5 0	„ Beard.
Prestwich	6	2	—	6 4 0	85 12 0	91 16 0	Do.
Pwllheli	5	2	—	6 9 0	10 2 0	16 11 0	„ Blaxall.
Reeth	2	—	—	—	—	—	Mr. Power.
Rhayader	2	—	—	—	—	—	Dr. Airy.
Richmond (Yorks)	5	2	—	4 5 0	5 8 0	9 13 0	Mr. Power.
Ripon	4	1	—	—	—	5 5 0	Dr. Beard.
Rochdale	7	5	—	4 14 0	49 6 0	79 14 0	Do.
Rochford	5	1	—	—	—	13 18 0	„ Airy.
Romford	7	5	—	3 1 0	31 7 0	88 2 0	Do.
Romney Marsh	3	2	—	0 18 0	6 12 0	7 10 0	„ Stevens
Rotherham	8	4	—	3 0 0	64 14 0	122 0 0	„ Beard.
Ruxby	8	—	—	—	—	—	Mr. Power.
Ruthin	3	1	—	—	—	11 18 0	Dr. Blaxall.
Rye	3	2	—	5 1 0	13 7 0	18 8 0	„ Stevens.
Saddleworth	1	—	—	—	—	—	„ Beard.
Saffron Walden	8	4	—	2 0 0	9 7 0	21 5 0	„ Airy.
Salford	8	2	—	108 6 0	126 17 0	235 3 0	„ Beard.
Samford	5	1	—	—	—	11 3 0	„ Airy.
Scarborough	5	2	—	8 1 0	29 2 0	37 3 0	Mr. Power.
Sedbergh	3	1	—	—	—	2 1 0	Dr. Beard.
Sedgfield	4	—	—	—	—	—	Mr. Power.
Sessdon	4	3	—	7 0 0	9 8 0	25 3 0	Dr. Ballard.
Selby	5	Under consideration.				—	„ Beard.
Settle	8	2	—	0 17 0	3 12 0	4 9 0	Do.
Sevenoaks	6	2	—	4 2 0	7 13 0	11 15 0	„ Stevens.
Shaftesbury	3	—	—	—	—	—	„ Blaxall.
Sheppey	2	2	—	6 0 0	25 2 0	31 2 0	„ Stevens.
Shepton Mallet	4	1	—	—	—	2 17 0	„ Blaxall.
Sherborne	4	—	—	—	—	—	Do.
Shifnal	4	1	—	—	—	4 14 0	Do.
Skipton	8	—	—	—	—	—	„ Beard.
Solihull	4	2	—	5 7 0	5 10 0	10 17 0	Mr. Power.
Southam	4	4	—	3 17 0	8 11 0	24 13 0	Do.
South Shields	3	2	—	51 2 0	86 10 0	137 12 0	Do.
Stafford	4	3	—	4 15 0	29 13 0	48 14 0	Dr. Ballard.
Steyning	5	2	1	2 5 4	10 14 0	18 9 4	„ Stevens.
Stockton	7	2	—	28 9 0	48 1 0	76 10 0	Mr. Power.
Stokesley	3	—	—	—	—	—	Do.
Stoke-on-Trent	5	4	1	3 19 4	122 9 0	263 3 4	Dr. Ballard.
Stone	4	2	—	8 6 0	15 9 0	23 15 0	Do.
Stow	8	4	—	1 10 0	7 9 0	18 7 0	„ Airy.
Stratford	7	2	—	7 18 0	18 5 0	26 3 0	„ Ballard.
Sturminster	4	1	—	—	—	8 14 0	„ Blaxall.
Sudbury	7	3	—	5 2 0	18 1 0	31 7 0	„ Airy.
Sunderland	5	3	—	22 10 0	85 11 0	181 16 0	Mr. Power.
Swansea	3	2	—	74 11 0	137 3 0	211 14 0	Dr. Airy.
Tadcaster	4	1	—	—	—	3 17 0	„ Beard.
Tamworth	5	—	—	—	—	—	„ Ballard.
Taunton	7	4	—	2 2 0	7 13 0	21 18 0	„ Blaxall.
Teesdale	7	2	—	8 8 0	10 4 0	18 12 0	Mr. Power.
Tendring	11	—	1	—	—	6 13 4	Dr. Airy.
Tenterden	6	4	—	1 10 0	8 11 0	18 18 0	„ Stevens.
Thakeham	2	2	—	10 6 0	12 7 0	22 13 0	Do.
Thame	6	2	—	8 12 0	16 3 0	24 15 0	„ Thorne.
Thanet, Isle of	4	1	—	—	—	10 14 0	„ Stevens.
Thirsk	5	4	—	1 4 0	5 16 0	11 8 0	Mr. Power.
Thorne	6	1	—	—	—	4 2 0	Dr. Beard.
Thrapston	5	—	—	—	—	—	„ Thorne.
Ticehurst	8	5	—	1 3 0	7 5 0	23 19 0	„ Stevens.
Tisbury	3	1	—	—	—	6 0 0	„ Blaxall.
Todmorden	2	—	—	—	—	—	„ Beard.
Tonbridge	6	4	—	6 5 0	32 4 0	76 5 0	„ Stevens.
Towcester	4	1	—	—	—	13 18 0	„ Thorne.
Toxteth Park	2	1	—	—	—	105 19 0	„ Beard.
Trecaron	2	—	2	4 16 0	6 8 8	11 4 8	„ Airy.
Tynemouth	7	4	—	16 0 0	36 3 0	113 11 0	Mr. Power.

App. No. 1.

Inspection of Public Vaccination.

Union.	No. of Vaccination Districts in Union.	No. of respective Vaccination Contractors recommended for Award.		Range of Award in each Union.		Total Sum awarded in the Union.	Name of Inspector.
		1st Class Award.	2nd Class Award.	Minimum.	Maximum.		
				£ s. d.	£ s. d.	£ s. d.	
Uckfield	6	4	—	8 14 0	13 13 0	46 6 0	Dr. Stevens.
Uttoxeter	5	—	—	—	—	—	„ Ballard.
Uxbridge	7	6	—	3 2 0	17 3 0	49 5 0	„ Thorne.
Wakefield	6	4	—	3 7 0	32 12 0	69 17 0	„ Beard.
Walsall	4	4	—	13 10 0	105 19 0	197 10 0	„ Ballard.
Wandsworth and Clapham.	8	5	—	2 12 0	83 11 0	198 0 0	„ Stevens.
Wangford	2	1	—	—	—	11 5 0	„ Airy.
Wareham and Purbeck.	7	1	—	—	—	5 1 0	„ Blaxall.
Warminster	5	2	—	5 6 0	6 16 0	12 2 0	Do.
Warrington	3	3	—	7 13 0	69 4 0	108 14 0	„ Beard.
Warwick	3	—	—	—	—	—	Mr. Power.
Weardale	5	—	—	—	—	—	Do.
Wellingborough	4	1	—	—	—	10 18 0	Dr. Thorn
Wellington (Salop)	3	—	1	—	—	31 12 8	„ Blaxal
Wellington (Som.)	6	—	—	—	—	—	Do.
Wells	4	1	—	—	—	9 11 0	Do.
Wem	4	2	—	1 17 0	7 0 0	8 17 0	Do.
Westbourne	3	2	—	5 15 0	7 8 0	13 3 0	„ Stevens.
West Bromwich	5	2	—	58 18 0	61 12 0	120 10 0	„ Ballard.
Westbury and Whorwellsdown.	4	2	—	2 4 0	2 7 0	4 11 0	„ Blaxall.
West Derby	6	4	—	3 17 0	177 10 0	349 10 0	„ Beard.
West Firle	3	2	—	1 6 0	1 14 0	3 0 0	„ Stevens.
West Ham	9	7	1	7 17 0	76 7 0	259 6 4	„ Airy.
West Hampnett	5	2	1	2 10 8	13 5 0	21 12 8	„ Stevens.
Wetherby	6	3	—	3 3 0	3 15 0	10 11 0	„ Beard.
Weymouth	6	3	—	5 1 0	15 11 0	29 12 0	„ Blaxall.
Wharfedale	3	1	—	—	—	12 8 0	„ Beard.
Whitby	4	1	1	6 2 0	8 7 0	14 9 0	Mr. Power.
Whitchurch (Salop)	4	3	—	1 11 0	9 17 0	18 19 0	Dr. Blaxall.
Whittlesey	2	1	—	—	—	10 11 0	Mr. Power.
Wigan	8	2	—	30 3 0	54 15 0	84 18 0	Dr. Beard.
Williton	7	1	—	—	—	5 9 0	„ Blaxall.
Wilton	4	1	—	—	—	6 10 0	Do.
Wimborne and Cranborne.	4	2	—	9 8 0	10 4 0	19 12 0	Do.
Wincanton	6	2	1	3 10 0	8 18 0	16 7 0	Do.
Winslow	3	1	—	—	—	6 10 0	Dr. Thorne.
Wisbeach	14	5	—	0 15 0	12 6 0	42 5 0	Mr. Power.
Witham	3	1	—	—	—	13 4 0	Dr. Airy.
Witney	5	2	—	10 17 0	16 6 0	27 3 0	„ Thorne.
Wolstanton and Burslem.	3	2	—	45 3 9	59 1 0	104 4 0	„ Ballard.
Wolverhampton	5	4	—	51 0 0	77 12 0	234 18 0	Do.
Woodbridge	4	2	1	3 18 0	11 3 0	23 16 4	„ Airy.
Woodstock	5	2	1	3 18 0	10 0 0	20 13 0	„ Thorne.
Woolwich	3	3	—	16 8 0	62 16 0	136 16 0	„ Stevens.
Wortley	3	2	—	9 10 0	13 4 0	22 14 0	„ Beard.
Wrexham	5	1	—	—	—	67 6 0	„ Blaxall.
Wycombe	12	4	—	2 3 0	13 0 0	21 7 0	„ Thorne.
Yeovil	7	3	1	3 1 0	7 7 0	23 9 0	„ Blaxall.
Total	1,782	730	78	—	—	15,696 19 8	

Supplementary List of Awards made in 1875 to Public Vaccinators in Unions which were inspected in 1874.

				£ s. d.	£ s. d.	£ s. d.	
Altrincham	6	4	—	8 9 0	22 9 0	60 13 0	Dr. Beard.
Brampton	1	1	—	—	—	18 1 0	„ Airy.
Total	7	5	—	—	—	78 14 0	

No. 2.

DIGEST, by DR. SEATON, of the VACCINATION OFFICERS' RETURNS (so far as received to January 31st, 1875) with regard to children whose births were registered in 1873.

The following return, which is the second annual return under the Vaccination Act, 1871, shows the continued successful working of that Act. Of 826,508 births returned to the Board by the several Vaccination Officers in England and Wales as registered during the year 1873,* the number which at the time the return was made had been registered as successfully vaccinated was 704,666 (being 85·2 per cent. of the whole) and the number registered as having died before they could be vaccinated was 80,512 (or 9·7 per cent of the whole). Of the remaining 41,330 children, 942 (or 0·113 per cent. of the whole) had been registered as insusceptible of successful vaccination†; 86 (or 0·01 per cent.) as having contracted small-pox before they could be vaccinated; 4,264 (or 0·51 per cent.) as having their vaccination postponed by medical certificate; leaving 36,038 (or 4·3 per cent.) as "removed," "not to be traced," or otherwise unaccounted for.‡ If from the 826,508 births returned by these officers deduction of the deaths without vaccination be first made, it appears that of the surviving 745,996 children, there were registered, at the time of the return, 94·45 per cent. as successfully vaccinated; 0·14 per cent. as either insusceptible of vaccination or as having had small-pox; and 0·57 per cent. as under medical certificate of postponement; leaving 4·8 per cent. as at that time still to account for.

Of the 36,038 registered births entered in the last column of the return as remaining unaccounted for, the very large majority were children who could not be found by the vaccination officers, usually because of the removal of the parents from the place of birth, but sometimes because of the birth itself having been registered (as is not uncommon in the case of illegitimate children) under a false name or false address. In many districts the amount of removals without vaccination which was returned was larger, and in some considerably larger, than it should have been, on account of *undue delay* on the part of the vaccination officer in instituting the inquiries which the Board's "Instructions to Vaccination Officers" direct. The remaining cases in the column (with the exception of a certain number in which vaccination had really been performed successfully, but which could not be registered as vaccinated on account of the legal certificate of vaccination not having been received by the vaccination officer) were cases which at

* From the Union of Tendring (914 births); from the Heworth and Whickham subdistricts of the Gateshead union (958 births); from the Moreton-on-the-Marsh subdistrict of the Shipton-on-Stour union (179 births), from the Sedbergh subdistrict of the Sedbergh union (57 births), no returns were received. The return from the Llansaintfraid subdistrict of the Llanfyllin union embraced only the latter half of the year, giving no information as to the 130 births registered during the first half.

† Of these, probably not one was *really* insusceptible. The cases included under this heading are children, who, being certified as having been three times unsuccessfully vaccinated, are no longer subject to the compulsory provisions of the law. It is satisfactory to note that the proportion of these cases on the present return is not much more than half what it was on the return for 1872.

‡ Correspondence in 1875 shows that many of these cases have since been accounted for.

the time of the return remained unvaccinated in the union or district of birth. Local imperfections in administrative machinery, as, *e.g.*, the employment of an insufficient number of vaccination officers or the employment of persons whose time was taken up too much by other work, want of activity or intelligence in the discharge of their duties on the part of the officers themselves, and want of due supervision of the officers by the Guardians were the main causes of this default, where it occurred. In four unions—Banbury, Dewsbury, Keighley, Leek—there was actual refusal on the part of the Guardians to give effect to the compulsory provisions of the law. The number of cases in which non-vaccination was due to direct refusal on the part of parents to comply with the law when required to do so, constitutes an utterly insignificant proportion of the cases entered in this column.

The proportion of cases not finally accounted for in England and Wales in 1873 was (including postponed cases) 4·8 per cent. of the registered births,—an improvement of 0·3 per cent. on the return for 1872. The proportion unaccounted for in the Metropolis (which on the present return is 8·7 per cent. of registered births, having in the return for 1872 been 8·8 per cent.) considerably exceeds, as it did in that year, the proportion in the kingdom at large. There are doubtless, as stated in last year's summary, special difficulties in dealing with the Metropolitan population; and these difficulties so differ in the several Metropolitan Unions that nothing like uniformity among them is to be looked for. But the differences shown in the returns to exist between the several Unions are much too great to be wholly accounted for in that way; and there can be no doubt that in many of the Metropolitan Unions there is great administrative defect, either by employment of an insufficient staff or by want of proper supervision.

When the Metropolitan Unions are deducted from the rest of the Kingdom the proportion of cases not finally accounted for is reduced to 4·2 per cent. In 40 of the counties in England and Wales the present return shows a smaller per-centage not finally accounted for than did the previous one; the improvement being proportionately most exhibited in Wales. On the return for 1872, there were twelve counties in England and seven in Wales in which the proportion of cases not finally accounted for amounted to, or exceeded, 5 per cent. of the registered births. On the present return there are but seven counties in England and three in Wales in which the proportion is so considerable as this; and in every one even of these ten counties, except Radnorshire, there is an improvement on the previous return.

In four counties, and in four only, is the proportion of cases not finally accounted for notably larger than on the return for 1872. In Worcestershire, where the proportion in 1872 was 3·3 per cent., it is on the present return 4·3 per cent., solely on account of a bad return from the union of Worcester; in the North Riding, where the proportion in 1872 was 3·8 per cent., it is on the present return 4·5 per cent., on account of a bad return from Guisborough; in the West Riding, where it was 4·4 per cent. in 1872, it is 6·6 per cent. on the present return, the difference in this case being much more than accounted for by the two unions—which have since become so notorious—of Dewsbury and Keighley, in which the Guardians refused to execute the law. Of 5,538 births registered in the Dewsbury union in 1873, no fewer than 1,735 are unaccounted for on this return, and of 1,931 births in Keighley no fewer than 788—making in the two unions 2,523 cases unaccounted for out of 7,269 births, or 34 per cent. The births in the remainder of the Riding were 66,988, of which all but 2,425, or 3·6 per cent., are finally accounted for. Apart then from those two unions, the present

return for the West Riding shows a considerably smaller, and not a larger, proportion of cases unaccounted for than did the return of 1872. The falling off in Radnorshire was entirely due to a bad return from Knighton.

In the summary for 1872, thirty-nine of the extra-Metropolitan Unions were singled out for unfavourable comment on account of the exceptionally large proportion of cases unaccounted for on their returns. It is to a certain extent satisfactory that only twelve of these should call for similar comment on the present return. These are Blandford, Cheltenham, Ashby-de-la-Zouch, Lincoln, Brentford, Pontypool, Banbury, Southampton, Burton-on-Trent, Leek, Newtown and Llanidloes, and Knighton; to which, however, have now to be added five Unions concerning which the previous return had given no special cause of complaint, viz., Hendon, Worcester, Guisborough, Dewsbury, Keighley. The returns from these seventeen unions, as compared with the rest of extra-Metropolitan England, give the following results :—

——	Births.	Cases unaccounted for.	Per-centage.
Seventeen unions as above -	27,560	5,938	21
Remainder of extra-Metropolitan England - -	680,332	23,930	3·5

Thus more than a fifth part of the cases unaccounted for in extra-Metropolitan England were from these seventeen unions. The danger, however, which is entailed by the indifference, neglect, or opposition of a few local authorities cannot, unfortunately, be limited to the localities themselves, but extends more or less over the kingdom.

The marked, though slight, improvement which this return shows over that for 1872 is the more satisfactory that during 1873 "the natural stimulus of Vaccination"—the SMALL-POX was comparatively absent from the country. In 1872 the recent epidemic of that disease was still raging, the registered deaths from it in that year being 19,094. In 1873 the deaths from small-pox were but 2,364. In my Report on that epidemic, which was published in the last Annual Report of the Medical Officer, I traced (p. 77) the effect of the system established by the Vaccination Laws, 1867 and 1871, in reducing the small-pox mortality in that portion of the population whose age brought it within their influence—the proportionate rate of small-pox mortality under five years of age to the total small-pox mortality in England and Wales having then already been reduced from 55 per cent. (which was its former rate) to 33½ per cent. in 1871, and to 30 per cent. in 1872. The Registrar-General's Abstracts for 1873, which have been published since my Report was made, show, as was anticipated, a still further reduction in that proportion: of the 2,364 small-pox deaths in England and Wales in that year, only 587 were in children under five years of age, or less than 25 per cent.

App. No. 2.

Digest of Vaccination Returns.

RETURNS, 1873.

—	Births.	Successfully Vaccinated.	Insusceptible of Vaccination.	Had Small Pox.	Dead, Unvaccinated.	Vaccination postponed.	Remaining.	Percentage of Children not finally accounted for, including Cases postponed.
ENGLAND AND WALES.	826,508	704,666	942	86	80,512	4,264	36,038	4·8
Do., excluding Metropolitan Unions.	707,852	607,892	691	82	69,319	3,510	26,358	4·2
The Metropolitan Unions.	118,656	96,774	251	4	11,193	754	9,680	8·7
Counties.								
Bedford	5,223	4,557	—	—	556	31	79	2·1
Berks	7,231	6,458	10	—	567	54	142	2·7
Bucks	5,233	4,619	9	—	463	26	116	2·7
Cambridge	6,443	5,629	3	—	616	31	164	3·08
Chester	18,981	16,474	12	1	1,828	83	583	3·5
Cornwall	10,974	9,460	14	5	1,107	92	296	3·5
Cumberland	7,962	7,022	6	7	776	25	126	1·8
Derby	12,485	10,769	20	—	1,386	51	259	2·4
Devon	18,097	15,915	13	1	1,501	140	527	3·6
Dorset	5,503	4,846	1	—	381	36	239	4·9
Durham	35,574	29,894	34	6	4,053	159	1,428	4·1
Essex	14,379	12,731	11	1	1,208	63	365	2·9
Gloucester	16,066	13,840	12	1	1,451	36	726	4·7
Hereford	3,334	2,899	3	—	271	21	140	4·8
Herts	7,128	6,408	9	1	569	19	122	1·9
Hunts	1,849	1,677	—	—	145	9	18	1·4
Kent (extra metropolitan).	20,520	18,313	25	1	1,650	85	446	2·6
Lancaster	115,350	99,417	65	4	11,754	324	3,786	3·5
Leicester	10,444	8,724	9	—	1,221	41	449	4·6
Lincoln	13,839	11,589	11	—	1,494	118	627	5·3
Middlesex (extra metropolitan).	8,483	6,711	41	4	701	34	992	12·0
Monmouth	8,688	7,322	6	—	827	45	488	6·6
Norfolk	13,068	11,306	13	2	1,316	63	368	3·2
Northampton	9,048	7,724	9	1	957	46	311	3·9
Northumberland	15,663	13,495	33	1	1,655	74	405	3·0
Nottingham	13,495	11,168	7	1	1,514	129	676	5·9
Oxford	5,741	4,809	6	—	558	36	332	6·4
Rutland	707	630	1	—	65	3	8	1·5
Shropshire	8,422	7,457	10	—	721	26	208	2·7
Somerset	14,780	13,019	23	—	1,218	77	443	3·5
Southampton	16,608	14,565	31	2	1,302	152	556	4·3
Stafford	31,930	27,377	22	4	3,177	89	1,261	4·2
Suffolk	11,056	9,710	4	—	942	56	344	3·6
Surrey (extra metropolitan).	12,007	10,265	7	1	920	170	644	6·7
Sussex	12,972	11,327	21	—	1,027	175	422	4·6
Warwick	23,667	20,488	23	8	2,485	56	607	2·8
Westmoreland	1,981	1,802	7	—	155	6	11	·8
Wilts	7,696	6,933	4	—	571	50	138	2·4
Worcester	18,878	16,104	25	7	1,930	108	704	4·3
York, E.R.	11,118	9,487	34	—	1,165	53	379	3·8
York, N.R.	8,440	7,141	9	2	905	75	308	4·5
York, W.R.	74,257	60,912	57	9	8,331	203	4,745	6·6

App No. 2.

Digest of Vaccination Returns.

—	Births.	Successfully Vaccinated.	Insusceptible of Vaccination.	Had Small Pox.	Dead, Unvaccinated.	Vaccination postponed.	Remaining.	Percentage of Children not finally accounted for, including Cases postponed.
WALES.								
Anglesey - -	906	789	—	—	74	8	35	4·7
Brecknock -	1,810	1,562	—	—	162	35	51	4·7
Cardigan - -	2,259	1,875	—	—	200	26	158	8·1
Carmarthen -	4,201	3,802	5	—	345	10	39	1·1
Carnarvon -	3,181	2,857	2	—	272	22	28	1·5
Denbigh - -	2,711	2,317	1	—	272	49	72	4·4
Flint - -	2,695	2,384	3	—	244	10	54	2·3
Glamorgan -	17,518	15,297	16	12	1,623	75	495	3·2
Merioneth -	2,032	1,740	—	—	202	34	56	4·4
Montgomery -	2,127	1,720	3	—	212	11	181	9·0
Pembroke -	2,455	2,152	1	—	209	41	52	2·8
Radnor - -	637	404	—	—	65	19	149	26·3
UNIONS.								
METROPOLITAN UNIONS.								
Bethnal Green -	5,036	3,993	4	—	508	16	515	10·5
Camberwell -	4,509	3,699	2	—	417	26	365	8·6
Chelsea - -	2,350	1,936	7	—	266	3	138	6·0
Fulham - -	2,661	2,225	8	—	243	15	170	6·9
George's, St. -	4,284	3,689	29	—	381	10	175	4·3
George St., East -	1,855	1,408	3	—	207	16	221	12·7
Giles and George, S.S.	1,770	1,330	1	—	179	12	248	14·6
Greenwich -	3,975	3,503	4	—	323	15	130	3·6
Hackney - -	4,453	3,113	8	1	401	101	829	20·8
Hampstead -	870	777	2	—	20	7	64	8·1
Holborn - -	6,194	4,996	5	—	659	47	487	8·6
Islington - -	8,416	7,125	16	—	700	62	513	6·8
Kensington -	4,111	3,395	17	—	395	26	278	7·3
Lambeth - -	8,348	6,469	30	2	817	14	1,016	12·3
Lewisham -	1,776	1,610	4	—	121	2	39	2·3
London, City -	1,752	1,466	5	—	167	43	71	6·5
Mary-le-bone -	5,003	3,925	7	—	554	26	491	10·3
Mile End Old Town.	3,860	3,109	10	—	363	30	348	9·7
Olave, St. -	4,972	4,173	12	—	452	18	317	6·7
Paddington -	2,832	2,316	7	—	252	52	205	9·0
Pancras, St. -	7,961	6,530	29	—	695	5	702	8·8
Poplar - -	5,223	4,387	9	—	516	9	302	5·9
Saviour, St. -	6,805	5,290	3	—	725	69	718	11·5
Shoreditch -	5,081	4,092	14	1	478	45	451	9·7
Stepney - -	2,074	1,576	—	—	222	14	262	13·3
Strand - - -	1,020	831	3	—	94	3	89	9·0
Wandsworth and Clapham.	4,951	4,342	6	—	415	21	167	3·8
Westminster -	1,363	1,181	—	—	135	4	43	3·4
Whitechapel -	2,667	2,155	1	—	262	34	215	9·3
Woolwich -	2,484	2,133	5	—	226	9	111	4·8

App. No. 2.

Digest of Vaccination Returns.

—	Births.	Successfully Vaccinated.	Insusceptible of Vaccination.	Had Small Pox.	Dead, Unvaccinated.	Vaccination postponed.	Remaining.
BEDFORDSHIRE.							
Ampthill	616	539	—	—	68	3	6
Bedford	1,354	1,219	—	—	125	6	4
Biggleswade	1,001	878	—	—	112	2	9
Leighton Buzzard	702	615	—	—	68	1	18
Luton	1,224	1,017	—	—	151	18	38
Woburn	326	289	—	—	32	1	4
BERKS.							
Abingdon	660	594	2	—	60	2	2
Bradfield	519	484	—	—	34	1	—
Cookham	481	442	—	—	24	5	10
Easthampstead	290	272	1	—	12	3	2
Faringdon	449	399	2	—	39	2	7
Hungerford	551	485	—	—	50	9	7
Newbury	601	528	4	—	50	12	7
Reading	1,362	1,192	—	—	135	12	23
Wallingford	446	407	1	—	30	—	8
Wantage	555	501	—	—	42	2	10
Windsor	813	696	—	—	61	2	54
Wokingham	504	458	—	—	30	4	12
BUCKS.							
Amersham	688	624	1	—	52	2	9
Aylesbury	804	705	—	—	60	12	27
Buckingham	406	352	2	—	37	4	11
Eton	823	726	—	—	66	1	30
Newport Pagnell	847	747	—	—	91	2	7
Winslow	282	263	—	—	15	1	3
Wycombe	1,373	1,207	6	—	140	4	16
CAMBRIDGE.							
Cambridge	1,002	877	—	—	91	9	25
Caxton and Arrington	384	353	—	—	30	—	1
Chesterton	962	841	—	—	87	8	26
Ely	763	637	1	—	89	2	34
Linton	456	406	—	—	35	5	10
Newmarket	970	856	1	—	81	—	32
North Witchford	527	465	—	—	56	1	5
Whittlesey	217	189	—	—	24	1	3
Wisbeach	1,162	1,005	1	—	123	5	28
CHESHIRE.							
Altrincham	1,665	1,471	1	—	140	5	48
Birkenhead	3,205	2,693	2	—	275	35	200
Tarvin	331	300	—	—	21	1	9
Chester	1,419	1,236	2	—	137	—	44
Congleton	1,366	1,221	1	1	131	5	7
Macclesfield	1,992	1,717	1	—	252	6	16
Nantwich	1,974	1,665	1	—	176	7	125
Northwich	1,387	1,240	2	—	137	1	7
Runcorn	1,201	1,081	—	—	102	3	15
Stockport	3,656	3,142	2	—	397	17	98
Wirrall	785	708	—	—	60	3	14

—	Births.	Successfully Vaccinated.	Insusceptible of Vaccination.	Had Small Pox.	Dead, Unvaccinated.	Vaccination postponed.	Remaining.
CORNWALL.							
Austell, St.	1,066	938	2	1	106	3	16
Bodmin	569	494	—	—	45	3	27
Camelford	263	232	1	—	28	—	2
Columb, St., Major	518	456	—	—	46	6	10
Falmouth	737	643	—	—	76	7	11
Germans, St.	516	469	—	—	38	4	5
Helston	857	706	1	1	95	3	51
Launceston	500	467	—	—	28	2	3
Liskeard	988	887	—	—	55	7	39
Penzance	1,817	1,535	3	1	238	17	23
Redruth	1,728	1,466	3	—	204	15	40
Stratton	245	195	—	—	14	11	25
Truro	1,170	972	4	2	134	14	44
CUMBERLAND.							
Alston with Garrigill	163	144	—	—	18	—	1
Bootle	337	297	—	—	33	—	7
Brampton	282	251	—	—	28	—	3
Carlisle	1,463	1,327	—	—	129	—	7
Cockermouth	1,922	1,720	3	2	181	5	11
Longtown	243	214	—	—	20	7	2
Penrith	763	686	2	—	63	3	9
Whitehaven	2,092	1,763	1	5	244	8	71
Wigton	697	620	—	—	60	2	15
DERBYSHIRE.							
Ashbourne	600	541	—	—	47	2	10
Bakewell	888	761	—	—	86	—	41
Belper	2,000	1,790	4	—	196	3	7
Chapel-en-le-Frith	506	431	1	—	47	3	24
Chesterfield	3,630	3,138	10	—	394	16	72
Derby	2,522	2,130	3	—	336	8	45
Glossop	695	567	1	—	96	—	31
Hayfield	405	346	—	—	43	7	9
Shardlow	1,239	1,065	1	—	141	12	20
DEVONSHIRE.							
Axminster	533	469	—	—	43	6	15
Barnstaple	1,090	992	1	1	77	7	12
Bideford	616	567	—	—	39	1	9
Crediton	531	489	—	—	31	—	11
East Stonehouse	590	517	—	—	58	6	9
Exeter	1,051	865	—	—	137	4	45
Holsworthy	300	273	—	—	15	1	11
Honiton	746	634	4	—	90	4	14
Kingsbridge	619	539	1	—	55	7	17
Newton Abbott	1,943	1,737	—	—	151	14	41
Okehampton	553	449	—	—	29	—	75
Plymouth	2,092	1,771	2	—	230	26	63
Plympton St. Mary	652	550	—	—	45	28	29
South Molton	536	473	—	—	43	2	18
Stoke Damerel	1,488	1,343	—	—	104	8	33
Tavistock	921	816	2	—	61	1	41
Thomas, St.	1,405	1,232	—	—	118	14	41
Tiverton	845	753	1	—	79	1	11
Torrington	453	401	1	—	29	6	16
Totnes	1,133	1,045	1	—	67	4	16

App. No. 2.

Digest of Vaccination Returns.

—	Births.	Successfully Vaccinated.	Insusceptible of Vaccination.	Had Small Pox.	Dead, Unvaccinated.	Vaccination postponed.	Remaining.
DORSET.							
Beaminster	384	342	—	—	27	7	8
Blandford	379	268	—	—	16	2	93
Bridport	559	488	—	—	49	4	18
Cerne	213	198	—	—	10	—	5
Dorchester	523	481	—	—	36	2	4
Poole	496	440	—	—	38	7	11
Shaftesbury	365	306	—	—	32	4	23
Sherborne	411	363	—	—	33	—	15
Sturminster	309	281	—	—	21	2	5
Wareham and Purbeck	492	447	—	—	31	1	13
Weymouth	871	781	1	—	51	1	37
Wimborne and Cranborne	501	451	—	—	37	6	7
DURHAM.							
Auckland	3,588	2,972	3	—	476	—	137
Chester-le-Street	1,668	1,460	—	—	193	1	14
Darlington	1,727	1,381	1	2	204	9	130
Durham	2,746	2,338	11	—	276	24	97
Easington	1,742	1,482	3	—	202	8	47
Gateshead*	2,926	2,264	1	—	373	29	259
Hartlepool	1,905	1,657	1	2	221	7	17
Houghton-le-Spring	1,353	1,154	—	—	145	1	53
Lanchester	2,152	1,862	1	2	237	6	44
Sedgefield	816	669	—	—	101	12	34
South Shields	3,772	3,064	2	—	421	—	285
Stockton	4,496	3,864	5	—	463	50	114
Sunderland	5,367	4,585	6	—	609	6	161
Teesdale	631	559	—	—	56	6	10
Weardale	685	583	—	—	76	—	26
ESSEX.							
Billericay	491	432	1	—	38	11	9
Braintree	594	541	2	—	43	1	7
Chelmsford	1,022	895	1	—	101	6	19
Colchester	860	753	1	—	76	7	23
Dunmow	590	538	1	—	43	2	6
Epping	623	533	1	1	47	2	39
Halstead	521	449	—	—	49	5	18
Lexden and Winstree	831	740	—	—	80	—	11
Maldon	831	746	—	—	59	—	26
Ongar	337	276	—	—	26	2	33
Orsett	431	393	—	—	30	—	8
Rochford	723	647	2	—	62	—	12
Romford	1,142	946	2	—	110	13	71
Saffron Walden	592	528	—	—	48	3	13
Tendring†	—	—	—	—	—	—	—
West Ham	4,329	3,890	—	—	371	11	57
Witham	462	424	—	—	25	—	13
GLOUCESTERSHIRE.							
Bristol	2,021	1,701	—	—	210	3	107
Cheltenham	1,369	1,029	—	1	142	—	197
Chipping Sodbury	502	403	—	—	52	—	47
Cirencester	680	601	1	—	54	5	19

* No returns from Heworth and Whickham sub-districts (958 births registered).
† No returns from Tendring Union (914 births registered).

—	Births.	Successfully Vaccinated.	Insusceptible of Vaccination.	Had Small Pox.	Dead, Unvaccinated.	Vaccination postponed.	Remaining.
GLOUCESTER—*cont.*							
Clifton	4,976	4,284	2	—	466	7	217
Dursley	348	316	—	—	26	3	3
Gloucester	1,401	1,224	1	—	132	4	40
Newent	319	287	—	—	28	3	1
Northleach	306	277	—	—	22	1	6
Stow-on-the-Wold	286	239	6	—	24	2	15
Stroud	1,273	1,148	1	—	107	1	16
Tetbury	166	156	—	—	10	—	—
Tewkesbury	426	379	1	—	40	2	4
Thornbury	582	534	—	—	35	3	10
Westbury-on-Severn	923	829	—	—	67	2	25
Wheatenhurst	204	193	—	—	10	—	1
Winchcomb	284	240	—	—	26	—	18
HEREFORDSHIRE.							
Bromyard	337	291	—	—	38	4	4
Dore	234	216	—	—	12	1	5
Hereford	915	809	—	—	84	2	20
Kington	333	288	—	—	31	—	14
Ledbury	376	327	—	—	28	3	18
Leominster	404	320	—	—	33	7	44
Ross	506	460	—	—	34	—	12
Weobley	229	188	3	—	11	4	23
HERTS.							
St. Albans	733	653	—	—	69	—	11
Barnet	779	701	—	—	64	1	13
Berkhampstead	509	447	—	—	42	1	19
Bishop's Stortford	668	619	—	—	40	1	8
Buntingford	218	194	—	—	17	3	4
Hatfield	205	187	—	—	16	1	1
Hemel Hempstead	459	401	—	—	49	1	8
Hertford	491	433	—	1	37	5	15
Hitchin	953	849	3	—	91	—	10
Royston	652	584	—	—	59	3	6
Ware	525	485	3	—	27	—	10
Watford	858	780	3	—	56	3	16
Welwyn	78	75	—	—	2	—	1
HUNTS							
Huntingdon	658	595	—	—	51	5	7
St. Ives	567	526	—	—	39	—	2
St. Neots	624	556	—	—	55	4	9
KENT (extra-metropolitan).							
Ashford, East	404	369	4	—	22	4	5
Ashford, West	538	487	—	—	41	2	8
Blean	590	547	—	—	38	—	5
Bridge	328	291	—	—	27	—	10
Bromley	1,216	1,024	2	—	115	4	71
Canterbury	498	428	—	—	55	4	11
Cranbrook	418	368	2	—	30	1	17
Dartford	1,525	1,373	1	—	113	10	28
Dover	1,099	919	1	—	116	6	57

App. No. 4

Digest of Vaccination Returns.

—	Births.	Successfully Vaccinated.	Insusceptible of Vaccination.	Had Small Pox.	Dead, Unvaccinated.	Vaccination postponed.	Remaining.
KENT—*cont.*							
Eastry	835	750	2	—	55	10	18
Elham	866	799	1	—	51	4	11
Faversham	795	727	—	—	63	2	3
Gravesend and Milton	588	531	—	—	49	—	8
Hollingbourn	452	402	2	—	42	1	5
Hoo	113	100	1	—	7	1	4
Maidstone	1,343	1,185	2	—	112	11	33
Malling	800	718	—	—	64	1	17
Medway	1,809	1,617	2	1	157	1	31
Milton	766	703	1	—	53	—	9
North Aylesford	815	739	1	—	66	—	9
Romney Marsh	191	168	—	—	19	—	4
Seven Oaks	812	738	—	—	51	7	16
Sheppey	580	522	—	—	37	1	20
Tenterden	342	302	—	—	30	—	10
Thanet, I. of	1,292	1,144	—	—	127	5	16
Tonbridge	1,505	1,362	3	—	110	10	20
LANCASHIRE.							
Ashton-under-Lyne	5,177	4,554	2	—	524	14	83
Barton-upon-Irwell	2,031	1,725	—	—	197	14	95
Blackburn	5,978	5,321	5	—	605	3	44
Bolton	6,609	5,805	3	—	650	1	150
Burnley	3,475	3,027	5	—	374	21	48
Bury	4,121	3,596	3	—	429	15	78
Chorley	1,580	1,376	1	—	178	3	22
Chorlton	8,563	7,340	3	—	904	17	299
Clitheroe	691	604	1	—	72	4	10
Fylde, The	1,049	943	—	—	87	—	19
Garstang	384	350	—	—	27	—	7
Haslingden	3,073	2,715	1	—	298	9	50
Lancaster	1,092	956	—	—	111	11	14
Leigh	1,799	1,601	2	—	163	—	33
Liverpool	7,893	6,441	3	—	972	8	469
Lunesdale	194	184	—	—	7	1	2
Manchester	6,797	5,726	4	2	805	4	256
Oldham	5,265	4,519	5	—	571	15	155
Ormskirk	2,006	1,786	1	—	183	7	29
Prescot	4,095	3,439	—	—	431	15	210
Preston	4,519	3,910	2	2	449	18	138
Prestwich	3,222	2,824	3	—	276	9	110
Rochdale	4,039	3,363	4	—	468	27	177
Salford	5,791	4,974	3	—	609	27	178
Todmorden	1,078	920	—	—	137	1	20
Toxteth Park	3,371	2,916	3	—	261	11	180
Ulverstone	2,943	2,491	2	—	287	37	126
Warrington	2,343	1,762	1	—	181	8	391
West Derby	10,731	9,395	7	—	963	18	348
Wigan	5,441	4,854	1	—	535	6	45
LEICESTERSHIRE.							
Ashby-de-la-Zouch	1,073	792	—	—	110	1	170
Barrow-on-Soar	810	662	—	—	104	2	42
Billesdon	198	173	—	—	17	—	8
Blaby	538	443	1	—	74	10	10
Hinckley	631	539	1	—	79	1	11
Leicester	4,446	3,730	6	—	555	5	150

—	Births.	Successfully Vaccinated.	Insusceptible of Vaccination.	Had Small Pox.	Dead, Unvaccinated.	Vaccination postponed.	Remaining.
LEICESTERSHIRE (cont.)							
Loughborough	780	648	1	—	100	5	26
Lutterworth	372	350	—	—	18	1	3
Market Bosworth	482	415	—	—	57	1	9
Market Harborough	495	443	—	—	40	2	10
Melton Mowbray	619	529	—	—	67	13	10
LINCOLNSHIRE.							
Boston	1,185	1,016	—	—	114	7	48
Bourn	612	539	1	—	53	1	18
Caistor	1,785	1,321	—	—	321	8	135
Gainsborough	821	663	1	—	94	12	51
Glanford Brigg	1,220	1,082	—	—	114	5	19
Grantham	999	898	—	—	84	5	12
Holbeach	644	557	2	—	67	1	17
Horncastle	676	607	1	—	49	2	17
Lincoln	1,900	1,433	2	—	258	41	166
Louth	1,065	922	—	—	89	16	38
Sleaford	724	651	—	—	64	4	5
Spalding	737	658	2	—	65	1	11
Spilsby	899	753	2	—	69	7	68
Stamford	572	489	—	—	53	8	22
MIDDLESEX (extra-metropolitan).							
Brentford	2,485	1,742	4	—	199	5	535
Edmonton	3,090	2,578	5	2	274	10	221
Hendon	1,427	1,085	32	—	108	15	187
Staines	701	613	—	1	56	3	28
Uxbridge	780	693	—	1	64	1	21
MONMOUTHSHIRE.							
Abergavenny	813	689	—	—	98	5	21
Bedwelty	2,389	2,072	2	—	204	11	100
Chepstow	570	501	1	—	45	10	13
Monmouth	1,087	939	2	—	108	4	34
Newport	2,393	2,096	1	—	237	1	45
Pontypool	1,436	1,025	—	—	135	1	275
NORFOLK.							
Aylsham	524	477	—	—	29	—	18
Blofield	338	290	—	—	39	4	5
Depwade	772	630	6	—	82	11	43
Docking	583	501	1	—	67	2	12
Downham	627	545	—	1	67	3	11
Erpingham	582	519	—	—	49	3	11
Faith, St.	351	320	—	—	29	1	1
Flegg, E. and W.	311	232	—	—	34	1	44
Forehoe	347	289	—	—	43	5	10
Freebridge Lynn	384	342	—	—	37	2	3
Guiltcross	301	259	—	—	29	5	8
Henstead	292	258	—	—	27	—	7
King's Lynn	460	400	3	1	50	—	6
Loddon and Clavering	405	362	—	—	32	1	10
Mitford and Launditch	793	716	—	—	60	2	15
Norwich	2,668	2,318	2	—	286	2	60
Swaffham	328	289	—	—	23	1	15

App. No. 2.

Digest of Vaccination Returns.

—	Births.	Successfully Vaccinated.	Insusceptible of Vaccination.	Had Small Pox.	Dead, Unvaccinated.	Vaccination postponed.	Remaining.
NORFOLK—*cont.*							
Thetford	580	526	—	—	32	1	21
Smallburgh	453	383	—	—	51	—	19
Walsingham	532	470	—	—	43	2	17
Wayland	329	271	1	—	45	4	8
Yarmouth, Gt.	1,108	909	—	—	162	13	24
NORTHAMPTONSHIRE							
Brackley	412	346	3	—	46	3	14
Brixworth	363	309	—	—	38	3	13
Daventry	603	519	2	1	59	—	22
Hardingstone	359	326	—	—	29	1	3
Kettering	846	753	—	—	80	1	12
Northampton	2,055	1,680	3	—	222	8	142
Oundle	427	376	—	—	42	2	7
Peterborough	1,327	1,172	—	—	138	2	15
Potterspury	410	341	—	—	42	5	22
Thrapston	551	486	—	—	59	1	5
Towcester	429	381	1	—	40	2	5
Wellingborough	1,266	1,035	—	—	162	18	51
NORTHUMBERLAND.							
Alnwick	592	511	3	—	55	4	19
Belford	156	141	1	—	10	1	3
Bellingham	188	174	—	—	11	—	3
Berwick-on-Tweed	599	541	—	—	44	9	5
Castle Ward	683	605	—	—	72	1	5
Glendale	318	298	3	—	12	—	5
Haltwhistle	222	205	1	—	13	1	2
Hexham	1,058	917	3	—	93	5	40
Morpeth	1,654	1,487	7	—	144	4	12
Newcastle-on-Tyne	5,722	4,770	9	1	732	20	190
Rothbury	171	154	—	—	11	—	6
Tynemouth	4,300	3,692	6	—	458	29	115
NOTTINGHAMSHIRE.							
Basford	3,897	3,302	1	—	451	14	129
Bingham	406	358	—	—	40	2	6
East Retford	652	581	—	—	64	1	6
Mansfield	1,476	1,234	2	—	167	12	61
Newark	938	832	1	—	83	1	21
Nottingham	3,237	2,396	2	—	423	78	338
Radford	1,397	1,113	—	—	187	19	78
Southwell	569	519	—	—	24	—	26
Worksop	923	833	1	1	75	2	11
OXFORDSHIRE.							
Banbury	992	710	—	—	97	3	182
Bicester	491	420	—	—	50	5	16
Chipping Norton	609	538	1	—	61	1	8
Headington	760	606	—	—	81	7	66
Henley	572	516	2	—	35	3	16
Oxford	655	565	1	—	69	4	16
Thame	476	424	—	—	43	—	9
Witney	752	655	—	—	88	2	7
Woodstock	434	375	2	—	34	11	12

—	Births.	Successfully Vaccinated.	Insusceptible of Vaccination.	Had Small Pox.	Dead, Unvaccinated.	Vaccination postponed.	Remaining.
RUTLAND.							
Oakham	354	323	1	—	24	3	3
Uppingham	353	307	—	—	41	—	5
SALOP.							
Atcham	1,289	1,156	1	—	114	8	10
Bridgenorth	458	411	—	—	36	1	10
Church Stretton	189	174	—	—	9	1	5
Cleobury Mortimer	238	219	—	—	17	2	—
Clun	333	272	4	—	26	2	29
Drayton	423	381	—	—	32	1	9
Ellesmere	339	305	—	—	31	3	—
Ludlow	553	468	—	—	53	2	30
Madeley	1,099	969	4	—	108	2	16
Newport	482	417	—	—	41	1	23
Oswestry	862	793	—	—	58	—	11
Shiffnall	439	401	1	—	26	1	10
Wellington	1,046	937	—	—	104	—	5
Wem	301	272	—	—	25	2	2
Whitchurch	371	282	—	—	41	—	48
SOMERSET.							
Axbridge	1,073	963	2	—	87	6	15
Bath	1,908	1,591	2	—	179	3	133
Bedminster	2,223	1,937	—	—	197	22	67
Bridgwater	1,068	965	7	—	79	2	15
Chard	842	735	3	—	78	5	21
Clutton	713	639	1	—	55	—	18
Dulverton	179	165	—	—	11	—	3
Frome	717	655	1	—	48	3	10
Keynsham	844	747	—	—	74	1	22
Langport	525	471	—	—	33	1	20
Shepton Mallet	530	474	1	—	39	4	12
Taunton	947	837	1	—	91	4	14
Wellington	561	515	—	—	29	1	16
Wells	598	510	2	—	49	11	26
Williton	554	511	—	—	31	1	11
Wincanton	615	551	3	—	46	4	11
Yeovil	883	753	—	—	92	9	29
SOUTHAMPTON.							
Alresford	213	186	—	—	23	1	3
Alton	470	404	—	—	47	2	17
Alverstoke	782	722	1	—	53	—	6
Andover	527	489	2	—	32	1	3
Basingstoke	589	519	—	—	36	11	23
Catherington	85	76	—	—	6	—	3
Christchurch	532	466	1	—	35	13	17
Droxford	336	298	1	—	25	1	11
Fareham	508	454	—	—	43	1	10
Fordingbridge	217	207	—	—	8	—	2
Hartley Wintney	582	523	—	—	35	2	22
Havant	278	233	1	—	18	—	26

App. No. 2.

Digest of Vaccination Returns.

—	Births.	Successfully Vaccinated.	Insusceptible of Vaccination.	Had Small Pox.	Dead, Unvaccinated.	Vaccination postponed.	Remaining.
SOUTHAMPTON—*cont.*							
Hursley	86	81	—	—	5	—	—
Kingsclere	227	182	—	—	24	1	20
Lymington	332	287	—	—	24	3	18
New Forest	387	349	—	—	29	4	5
Petersfield	308	285	—	—	18	2	3
Portsea Island	4,044	3,629	4	2	349	9	51
Ringwood	149	141	—	—	4	—	4
Romsey	314	241	1	—	34	5	33
Southampton	1,541	1,207	2	—	160	27	145
South Stoneham	1,075	899	2	—	102	28	44
Stockbridge	216	203	1	—	11	—	1
Whitchurch	170	155	—	—	12	—	3
Wight, Isle of	1,901	1,669	14	—	124	33	61
Winchester	739	660	1	—	45	9	24
STAFFORDSHIRE.							
Wolstanton and Burslem	3,514	3,107	—	—	370	6	31
Burton-on-Trent	2,250	1,486	1	—	167	11	585
Cheadle	781	702	—	—	62	4	13
Leek	1,089	836	1	—	119	5	128
Lichfield	1,210	1,051	2	—	130	6	21
Newcastle-under-Lyme	1,254	1,091	—	—	129	—	34
Penkridge	1,049	867	1	—	119	6	56
Seisdon	481	432	—	—	39	3	7
Stafford	970	853	2	—	94	7	14
Stoke-on-Trent	3,970	3,442	1	—	413	9	105
Stone	857	784	1	—	64	1	7
Tamworth	681	552	1	1	67	11	49
Uttoxeter	426	404	—	—	17	1	4
Walsall	3,372	2,871	3	—	374	15	109
West Bromwich	4,863	4,348	4	3	467	2	39
Wolverhampton	5,163	4,551	5	—	546	2	59
SUFFOLK.							
Blything	816	725	—	—	50	8	33
Bosmere and Claydon	477	412	—	—	40	6	19
Bury St. Edmunds	475	409	—	—	51	4	11
Cosford	527	472	1	—	42	—	12
Hartismere	524	482	—	—	33	1	8
Hoxne	452	401	—	—	35	—	16
Ipswich	1,529	1,353	—	—	139	15	22
Mildenhall	293	270	—	—	14	1	8
Mutford and Lothingland	1,148	944	1	—	131	4	68
Plomesgate	578	522	—	—	38	4	14
Risbridge	591	546	—	—	33	2	10
Stamford	369	323	—	—	36	—	10
Stow	685	608	—	—	58	1	18
Sudbury	994	828	—	—	99	2	65
Thingoe	515	451	2	—	47	1	14
Wangford	446	385	—	—	45	4	12
Woodbridge	637	579	—	—	51	3	4

—	Births.	Successfully Vaccinated.	Insusceptible of Vaccination.	Had Small Pox.	Dead, Unvaccinated.	Vaccination postponed.	Remaining.
SURREY (extra-metropolitan).							
Chertsey	759	640	—	—	54	13	52
Croydon	2,967	2,419	3	1	260	72	212
Dorking	436	407	—	—	24	—	5
Epsom	933	759	1	—	63	14	96
Farnham	1,400	1,205	—	—	112	11	72
Godstone	416	377	—	—	27	2	10
Guildford	1,074	945	—	—	80	20	29
Hambledon	453	411	—	—	24	8	10
Kingston	1,898	1,592	2	—	153	19	132
Reigate	884	802	—	—	57	9	16
Richmond	787	708	1	—	66	2	10
SUSSEX.							
Battle	463	432	—	—	25	5	1
Brighton	2,782	2,407	1	—	284	20	70
Chailey	288	264	—	—	22	—	2
Chichester	228	184	—	—	15	—	29
Cuckfield	613	535	—	—	50	9	19
Eastbourne	497	419	—	—	30	3	45
East Grinstead	544	496	—	—	36	6	6
East Preston	641	571	2	—	53	9	6
Hailsham	413	356	1	—	26	4	26
Hastings	1,038	837	—	—	87	70	44
Horsham	616	562	—	—	36	6	12
Lewes	320	280	—	—	32	2	6
Midhurst	396	359	—	—	28	3	6
Newhaven	217	166	8	—	28	6	9
Petworth	313	293	—	—	14	5	1
Rye	352	310	—	—	26	—	16
Steyning	954	794	8	—	90	9	53
Thakeham	285	266	—	—	15	—	4
Ticehurst	592	513	—	—	47	5	27
Uckfield	649	603	—	—	34	1	11
Westbourne	215	184	—	—	12	4	15
West Firle	60	56	—	—	3	1	—
West Hampnett	496	440	1	—	34	7	14
WARWICKSHIRE.							
Alcester	636	548	1	—	76	2	9
Aston	6,825	5,976	6	4	700	7	132
Atherstone	428	384	—	—	34	3	7
Birmingham	9,295	7,949	10	4	1,010	20	302
Coventry	1,531	1,294	2	—	199	8	28
Foleshill	633	526	—	—	96	—	11
Meriden	273	243	—	—	17	4	9
Nuneaton	465	365	—	—	68	—	32
Rugby	715	641	—	—	58	—	16
Solihull	400	370	—	—	19	2	9
Southam	395	342	1	—	38	6	8
Stratford-on-Avon	704	620	1	—	55	2	26
Warwick	1,367	1,230	2	—	115	2	18

App. No. 2.

Digest of Vaccination Returns.

—	Births.	Successfully Vaccinated.	Insusceptible of Vaccination.	Had Small Pox.	Dead, Unvaccinated.	Vaccination postponed.	Remaining.
WESTMORELAND.							
East Ward	493	429	1	—	56	1	6
Kendal	1,272	1,170	4	—	88	5	5
West Ward	216	203	2	—	11	—	—
WILTSHIRE.							
Alderbury	726	673	1	—	43	—	9
Amesbury	251	232	—	—	17	—	2
Bradford	305	282	—	—	22	—	1
Calne	265	250	—	—	13	1	1
Chippenham	635	570	—	—	37	16	12
Cricklade and Wootton Bassett.	378	317	1	—	43	6	11
Devizes	585	541	—	—	37	2	5
Highworth and Swindon	1,181	1,058	1	—	84	10	28
Malmesbury	453	412	—	—	29	1	11
Marlborough	280	263	—	—	14	—	3
Melksham	611	530	—	—	67	2	12
Mere	250	221	—	—	24	—	5
Pewsey	352	315	—	—	22	1	14
Tisbury	281	259	—	—	14	1	7
Warminster	451	412	—	—	31	5	3
Westbury and Whorwelsdown.	387	339	1	—	39	3	5
Wilton	305	259	—	—	35	2	9
WORCESTERSHIRE.							
Bromsgrove	1,056	927	2	—	109	2	16
Droitwich	763	655	—	—	84	2	22
Dudley	6,514	5,550	9	1	719	50	185
Evesham	507	453	—	—	42	2	10
Kidderminster	1,195	932	5	—	156	20	82
King's Norton	2,516	2,224	6	—	216	20	50
Martley	465	409	—	—	33	1	22
Pershore	424	392	—	—	29	—	3
Shipston-on-Stour*	423	332	—	—	42	1	48
Stourbridge	3,254	2,813	2	6	358	10	65
Tenbury	218	184	—	—	19	—	15
Upton-on-Severn	555	510	1	—	38	—	6
Worcester	988	723	—	—	85	—	180
YORKSHIRE. (East Riding.)							
Beverley	689	540	—	—	76	2	71
Bridlington	535	439	1	—	73	7	15
Driffield	654	560	3	—	80	4	7
Howden	415	371	—	—	41	1	2
Kingston-upon-Hull	2,611	2,263	12	—	278	3	55
Patrington	265	237	—	—	18	1	9
Pocklington	517	438	—	—	57	2	20
Sculcoates	3,003	2,532	3	—	326	16	126
Skirlaugh	327	290	4	—	31	1	1
York	2,102	1,817	11	—	185	16	73

* No returns from Moreton in Marsh sub-district (179 births registered).

—	Births.	Successfully Vaccinated.	Insusceptible of Vaccination.	Had Small Pox.	Dead, Unvaccinated.	Vaccination postponed.	Remaining.
YORKSHIRE. (North Riding.)							
Aysgarth	142	123	—	—	17	1	1
Bedale	253	221	—	—	32	—	—
Easingwold	280	247	—	—	23	1	9
Guisborough	2,234	1,747	1	2	282	18	184
Helmsley Blackmoor	189	166	—	—	21	1	1
Kirkby Moorside	181	157	—	—	21	3	—
Leyburn	230	205	—	—	23	—	2
Malton	770	656	2	—	83	12	17
Northallerton	329	290	—	—	30	—	9
Pickering	489	390	3	—	63	6	27
Reeth	147	136	—	—	9	1	1
Richmond	382	348	—	—	24	4	6
Scarborough	1,161	977	1	—	143	11	29
Stokesley	344	308	2	—	27	5	2
Thirsk	388	352	—	—	27	1	8
Whitby	921	818	—	—	80	11	12
YORKSHIRE. (West Riding.)							
Barnsley	2,815	2,412	2	—	301	24	76
Bramley	1,928	1,649	1	—	199	2	77
Bradford	6,267	5,154	3	—	829	1	280
Bierley, North	4,422	3,774	1	—	510	24	113
Dewsbury	5,358	2,886	9	2	726	3	1,732
Doncaster	1,595	1,382	1	—	157	8	47
Eccleshall Bierlow	3,824	3,296	7	—	397	4	120
Goole	643	564	1	—	64	4	10
Halifax	5,552	5,030	2	1	459	12	48
Hemsworth	245	225	—	—	19	—	1
Holbeck	995	854	—	1	126	1	13
Huddersfield	5,167	4,562	3	2	532	5	63
Hunslet	2,186	1,858	1	—	301	2	24
Keighley	1,931	903	—	—	240	—	788
Knaresborough	574	494	5	—	59	3	13
Leeds	6,867	5,954	2	1	825	13	72
Ouseburn, Gt.	369	332	—	—	25	3	9
Pateley Bridge	257	242	—	—	14	1	—
Penistone	637	567	1	—	64	1	4
Pontefract	1,724	1,499	2	—	182	10	31
Ripon	478	436	—	—	31	5	6
Rotherham	2,756	2,403	2	1	285	9	56
Saddleworth	701	602	—	—	72	—	27
Sedbergh*	91	78	2	—	9	1	1
Selby	511	446	—	—	56	1	8
Settle	473	420	—	—	44	1	8
Sheffield	7,431	5,876	6	1	923	32	593
Skipton	1,050	911	—	—	107	4	28
Tadcaster	792	658	—	—	81	1	52
Thorne	522	414	—	—	51	3	54
Wakefield	2,915	2,414	4	—	304	3	190
Wetherby	412	341	2	—	29	10	30
Wharfedale	1,423	1,188	—	—	168	8	59
Wortley	1,346	1,088	—	—	142	4	112

* No return from Sedbergh sub-district (57 births registered).

App. No. 2.

Digest of Vaccination Returns.

—	Births.	Successfully Vaccinated.	Insusceptible of Vaccination.	Had Small Pox.	Dead, Unvaccinated.	Vaccination postponed.	Remaining.
ANGLESEY.							
Anglesey	426	374	—	—	32	2	18
Holyhead	480	415	—	—	42	6	17
BRECKNOCK.							
Brecknock	495	450	—	—	35	1	9
Builth	264	236	—	—	18	—	10
Crickhowell	735	609	—	—	78	34	14
Hay	316	267	—	—	31	—	18
CARDIGAN.							
Aberaeron	371	307	—	—	37	9	18
Aberystwith	799	644	—	—	65	13	77
Cardigan	477	410	—	—	33	—	34
Lampeter	293	242	—	—	37	2	12
Tregaron	319	272	—	—	28	2	17
CARMARTHEN.							
Carmarthen	1,061	949	—	—	89	7	16
Llanelly	1,564	1,409	—	—	145	1	9
Llandilo Fawr	601	557	—	—	38	2	4
Llandovery	437	397	5	—	33	—	2
Newcastle-in-Emlyn	538	490	—	—	40	—	8
CARNARVON.							
Bangor and Beaumaris	989	894	1	—	81	4	9
Carnarvon	1,193	1,059	—	—	113	10	11
Conway	388	354	—	—	27	5	2
Pwllheli	611	550	1	—	51	3	6
DENBIGH.							
Llanrwst	377	293	—	—	40	17	27
Ruthin	392	352	—	—	33	3	4
Wrexham	1,942	1,672	1	—	199	29	41
FLINT.							
St. Asaph	728	646	—	—	70	2	10
Hawarden	550	501	1	—	46	—	2
Holywell	1,417	1,237	2	—	128	8	42
GLAMORGAN.							
Bridgend and Cowbridge	1,113	990	—	—	82	2	39
Cardiff	2,889	2,410	2	—	313	14	150
Gower	315	286	—	—	23	2	4
Merthyr Tydfil	4,541	4,082	4	7	404	1	43
Neath	2,860	2,549	—	—	265	10	36
Pontypridd	2,732	2,329	9	5	306	15	68
Swansea	3,068	2,651	1	—	230	31	155

—	Births.	Successfully Vaccinated.	Insusceptible of Vaccination.	Had Small Pox.	Dead, Unvaccinated.	Vaccination postponed.	Remaining.
MERIONETH.							
Bala - - -	184	158	—	—	17	5	4
Corwen - - -	502	440	—	—	35	6	21
Dolgelly - - -	467	418	—	—	43	—	6
Festiniog - - -	879	724	—	—	107	23	52
MONTGOMERY.							
Llanfyllin* - -	428	354	—	—	59	1	14
Machynlleth - -	352	319	—	—	22	2	9
Forden - - -	547	490	—	—	42	4	11
Newtown and Llanidloes -	800	557	3	—	89	4	147
PEMBROKE.							
Haverfordwest - -	976	849	—	—	84	16	27
Narberth - - -	623	566	—	—	43	4	10
Pembroke - - -	856	737	1	—	82	21	15
RADNOR.							
Knighton - - -	328	175	—	—	38	9	106
Presteigne - -	105	87	—	—	8	4	6
Rhayader - - -	204	142	—	—	19	6	37

* No return for first half of 1873 from Llansaintfraid sub-district (130 births registered).

App. No. 3.

National Vaccine Establishment.

No. 3

Statistics of the National Vaccine Establishment and Educational Vaccinating Stations.

I.—Staff at end of 1875.

N.B.—The stations named in *italics* are Educational Vaccinating Stations, authorised by the Lords of the Privy Council, for the purposes of their Lordships' Order of December 1, 1859.

—	Name.	Vaccinating Station.	Day and Hour of Attendance.
Vaccinators supplying lymph for the public service, & salaried from the Parliamentary grant -	1. Mr. J. F. Marson -	*Surrey Chapel* -	Tues., Thurs.; 1.
	2. Mr. W. E. G. Pearse -	*Tottenham Court Chapel.*	Mon., Wednes.; 1.
Parochial and other Vaccinators not salaried from the Parliamentary grant, but contributing lymph at a fixed rate of payment.	1. Mr. E. S. Guest - -	*Manchester* -	Monday; 2.
	2–5. Dr. E. Robinson	*Birmingham*	2. Monday - 3. Tuesday - 4. Wednesday 5. Thursday - 11
	6. Dr. H. A. P. Robertson	*Bristol* - -	Wednesday; 10.
	7. Mr. A. B. Steele - -	*Liverpool* - -	Thursday; 2.
	8. Mr. E. L. Webb - -	*Pimlico* - -	Thursday; 10.
	9. Mr. J. Hawthorn - -	*Newcastle-on-Tyne.*	Wednesday; 3.
	10. Mr. W. E. G. Pearse -	*Westminster* -	Tuesday; 2.
	11–12. Mr. W. A. Summer	*Marylebone*	Monday - Wednesday 10.
	13. Mr. C. T. Blackman -	*Whitechapel* -	Wednesday; 11.
	14. Mr. F. Holmes - -	*Leeds* - -	Tuesday; 2.30.
	15. Dr. E. Lynes - -	Coventry - -	Tuesday; 12.
	16. Dr. H. Thomson - -	*Glasgow* - -	Monday; 12.
	17. Mr. C. H. Roper - -	*Exeter* - -	Thursday; 3.
	18. Mr. R. W. Dunn - -	*Strand* - -	Thursday; 11.
	19. Mr. M. Brownfield -	Bromley, Middlesex.	Tuesday; 3.
	20. Mr. J. Broadbent - -	Ancoats - -	Wednesday; 2.
	21. Mr. W. Skinner - -	*Sheffield* - -	Tuesday; 3.
	22. Dr. A. C. Clarke - -	Salford - -	Thursday; 2.
	23. Mr. N. Miskin - -	Waterloo - -	Tuesday; 2.
	24. Mr. T. F. Morrish -	Toxteth Park -	Tuesday; 11.
Teachers of Vaccination, not supplying lymph -	Dr. W. Husband - -	*Edinburgh* -	Wednes., Sat.; 12.
	Dr. R. D. Tannahill -	*Glasgow* -	Mond., Thurs.; 12.

II.—Sources and Amount of Lymph Supply in 1875.

App. No. 3.
National Vaccine Establishment.

N.B.—The stations marked in *italics* are Educational Vaccinating Stations, authorised by the Local Government Board.

—	Vaccinating Stations.	Number of Vaccinations performed at the Stations respectively.		Number of Charges of Lymph supplied from the Stations respectively.	
		Primary.	Re-vaccinations.	Charged Ivory Points.	Charged Tubes each estimated as equal to 10 Ivory Points.
Vaccinators salaried from the Parliamentary grant.	1. *Surrey Chapel* - -	671	65	14,865	—
	2. Battle Bridge* - -	518	—	—	273
	3. *Tottenham Court Chapel*	1,000	28	†188	904
		2,189	93	15,053	1,177
Parochial and other Vaccinators not salaried from the Parliamentary grant, but contributing lymph at a fixed rate of payment.	1. *Manchester* - - -	1,340	6	—	819
	2–5. *Birmingham* - -	5,804	193	—	3,952
	6. *Bristol* - - -	825	23	—	47
	7. *Liverpool* - - -	1,077	—	—	1,956
	8. *Pimlico* - - -	483	5	—	1,202
	9. *Newcastle-on-Tyne* -	685	—	—	1,070
	10. *Westminster* - -	1,037	6	—	1,222
	11–12. *Marylebone* - -	1,671	4	—	907
	13. *Whitechapel* - -	1,102	2	—	482
	14. *Leeds* - - - -	1,272	—	—	540
	15. Coventry - - -	1,015	—	—	797
	16. *Glasgow* - - -	1,475	—	—	1,763
	17. *Exeter* - - -	544	2	—	197
	18. *Strand* - - -	456	2	—	457
	19. Bromley - - -	881	3	—	814
	20. Ancoats - - -	1,287	—	—	4,013
	21. *Sheffield* - - -	1,186	—	—	264
	22. Salford - - -	999	1	—	1,744
	23. Waterloo - - -	630	1	—	1,713
	24. Toxteth Park - -	1,144	2	—	2,155
	Total - -	24,913	250	—	26,114
	General Total -	27,102	343	15,053	27,291

* Discontinued in September 1875 on the death of Mr. G. L. Cooper.
† This number includes 32 charged glasses, each estimated as equal to four charged ivory points.

App. No. 3. III.—Distribution of Lymph, 1875.

National Vaccine Establishment.

Number of applications:	
From medical practitioners in England and Wales	9,12
„ „ „ Ireland	
„ „ „ Scotland	21
„ the Army	50
„ the Navy and from the Emigration Department	6
„ Colonies	17
„ diplomatic and other foreign services	8
Total	10,17
Supplies sent out:	
Charged ivory points	21,77
„ squares of glass	3
„ capillary tubes	21,89

No. 4.

EXTRACT of MEDICAL INSPECTIONS made in 1875 with regard, generally, to the INCIDENCE OF DISEASE on particular places, and to consequent Questions concerning the LOCAL SANITARY ADMINISTRATION.

Place of Inquiry and Name of Inspector.	Ground of Inquiry.	Jurisdictions Concerned.	Chief Facts reported by the Inspector.
Alcester Town - (Warwickshire.) Population, 2,363. *Dr. Ballard.*	Local request - -	Alcester rural sanitary authority.	Want of proper sewering and drainage. Surface nuisances. Polluted wells. Privies imperfectly constructed and badly managed. Certain dwellings dirty, dilapidated, and unfit for habitation.
Barton - on - Irwell (Registration District. Lancashire.) Population, 51,571. *Dr. Stevens.*	Regis.-General's Return.	Barton urban sanitary authority.	High rate of mortality from zymotic diseases. Fever, diarrhœa, and scarlatina endemic. *Barton Urban Sanitary District.*—Watercourses much fouled by sewage; the Irwell especially is very offensive. Water supply insufficient and in some cases bad. Privies badly constructed, filthy, and productive of much nuisance. Houses unfit for habitation. Lodging-houses overcrowded and improperly conducted. No means of isolation or disinfection.
	"	Stretford urban sanitary authority.	*Stretford Urban Sanitary District.*—Defective sewerage. Polluted wells. Defective arrangements for excrement disposal. Houses unfit for habitation. Scavenging arrangements defective. Nuisance from badly managed laundries which are situated in a very unhealthy locality. No means of isolating cases of infectious disease.
	" "	Swinton urban sanitary authority.	*Swinton Urban Sanitary District.*—Part of district undrained. Privy nuisances. Nuisances from pig keeping. Houses unfit for habitation. No means of isolating cases of infectious disease.
	" "	Barton rural sanitary authority.	*Barton Rural Sanitary District.*—General want of sewerage and drainage. Great scarcity of water. Polluted wells. Nuisance from overfull middensteads. Houses unfit for habitation No means of isolation or disinfection.
Chatteris - - (Cambridgeshire.) Population, 4,749. *Mr. Radcliffe.*	Regis.-General's Return.	Chatteris urban sanitary authority.	High rate of mortality from fever. Privy pits in a porous soil and not water-tight. Wells often close to privy pits, from which there is soakage into soil.
Cheshunt - - (Herts.) Population, 7,518. *Dr. Thorne.*	Regis.-General's Return.	Cheshunt urban sanitary authority.	Prevalence of low-type diseases. Sewerage and drainage either very defective, or wanting altogether. Privies dilapidated and productive of nuisance. Want of systematic arrangements for refuse removal. Wells exposed to excremental pollution. No means of isolation or disinfection.
Croydon - - (Surrey.) Population, 55,652. *Dr. Buchanan.*	Local request - -	Croydon urban sanitary authority.	Enteric fever prevalent during the year. Sewer infection, and questions of water pollution. Report subjoined.
Faversham Registration. Sub-district. Kent. Population, 11,595. *Mr. W. H. Power.*	Regis.-General's Return.	Faversham urban sanitary authority. Faversham rural sanitary authority.	High mortality from scarlet fever. In older parts of the town houses and outbuildings huddled together on insufficient areas. Dwellings often small, dilapidated, and insufficiently ventilated. Private wells liable to pollution. Parts of town unsewered. Sink openings not properly trapped. Sewers neither flushed nor ventilated. Defective arrangements for excrement removal. No means of isolation or disinfection.

Area of Inquiry and Name of Inspector.	Ground of Inquiry.	Jurisdictions Concerned.	Chief Facts reported by the Inspect
7. Festiniog Registration. Sub-district. Population, 11,484. *Dr. Blaxall.*	Regis.-General's Return.	Festiniog rural sanitary authority.	Continued high rate of mortality fr zymotic disease. Epidemic of scar fever. Dirty, ill-ventilated, and ov crowded dwellings. Schools attend by infected children. Accumulati of filth. Want of privy accommo tion and proper drainage. Nuisanc Water supply exposed to polluti No means of isolation or disinfecti
8. Great Yarmouth (Norfolk and Suffolk.) Population, 44,500. *Dr. Airy.*	Regis.-General's Return.	Yarmouth urban sanitary authority. Mutford and Lothingland rural sanitary authority. East and West Flegg rural sanitary authority.	Continued prevalence of zym disease. Severe epidemic of scar fever. Houses so built as to res ventilation impossible. Scarlet fe very fatal in the "Rows." Hou on soil of unwholesome charac Sewers insufficiently ventilat Privies badly constructed, and d gerously close to dwellings. Def tive arrangements for excrement refuse removal. Nuisance fr slaughter-houses. Water sup partly obtained from polluted we Want of hospital accommodation.
9. Guisbrough Registration District, part of. (Yorks.) Population, 31,264. *Dr. Thorne.*	Regis.-General's Return	Guisbrough rural sanitary authority.	High general death rate. Much p valence of scarlet and enteric fever *Coatham.*—Wells exposed to polluti Sewers insufficiently ventilat Nuisances from middensteads. *Saltburn - by - the - Sea.* — Sewers efficiently ventilated. Nuisance fr middensteads. *Other parts of Rural Sanitary D trict.*—Rows of houses built back back, and, especially in *Brot and Eston*, frequently in cl proximity to noisome middenstea Water supply partly derived fr wells liable to pollution. Sewer generally defective. Sewers unve lated. Badly constructed midd privies in general use. Nuisa from middensteads and pigsties part of district adjoining Redcar.
	,, ,,	Normanby urban sanitary authority.	*South Bank and Tees Tilery*—Sew badly constructed and imperfe ventilated. Midden privies are general use and are productive much nuisance.
		Do.; and Ormesby urban sanitary authority.	*Normanby and Ormesby.*—Ent fever rarely absent. Water sup generally obtained from wells, m of which are exposed to polluti Frequent nuisances from mid privies. No means of isolatior disinfection.
	,, ,,	Redcar urban sanitary authority.	*Redcar.*—Some houses dirty, dil dated, and unfit for habita Sewers insufficiently ventila Midden privies. Badly constru and productive of serious nuisan
	,, ,,	Skelton urban sanitary authority.	*Skelton.*—Sewerage in some places defective. Midden privies in ge use, and so constructed as to e dangerous nuisance. Much nuis from slaughter-houses.
10. Handsworth Urban Sanitary District. Population, 14,359. *Dr Ballard.*	Regis.-General's Return	Handsworth urban sanitary authority.	Confirmation of Report recently m by the local officer of health; vi Waterclosets so situated n favour escape of foul air into ho Badly built cottages, without pr ventilation and in close proximi privies and ashpits. Drainage defective. Soil polluted by soa from cesspools. Wells frequ close to middensteads.
11. Holywell Registration District. (Flint.) Population, 43,517. *Dr. Blaxall.*	Regis.-General's Return	- - - -	High general death-rate; and ar ceedingly high death-rate scarlet fever.
	,, ,,	Holywell rural sanitary authority.	*Holywell Rural Sanitary Distri* Epidemic of scarlet fever, and sistence of the disease. Infected healthy children occupying the bed. No measures adopted to vent the spread of disease.

of Inquiry and e of Inspector.	Ground of Inquiry.	Jurisdictions Concerned.	Chief Facts reported by the Inspector.
ll Registration ct—*cont.*	Regis.-General's Return	Holywell rural sanitary authority.	crowding. Ill-ventilated and dilapidated dwellings. Exposure of excrement in large open middenstead. Accumulations of refuse in the vicinity of dwellings. Very inadequate water supply, and exposure of water to contamination. No public drainage. Pig-keeping nuisances.
	" "	Holywell urban sanitary authority.	*Holywell Urban Sanitary District.*—Epidemic of scarlet fever. Want of means for isolation and disinfection. Slaughter-houses in unwholesome relation to dwellings. Exposure of blood and offal, and also of refuse in the vicinity of houses. Very defective drainage. Privy nuisances. Dilapidated dwellings.
	" "	Flint urban sanitary authority.	*Flint Urban Sanitary District.*—Severe epidemic of scarlet fever. Persistent presence of the disease, also of typhoid fever. Infected bodies occupying inhabited rooms. Exposure of infected persons. No measures adopted to prevent the spread of contagion. Overcrowding. Beds occupied night and day. Dilapidated dwellings. Common lodging-houses (not registered) both dilapidated and overcrowded. Slaughter-houses not registered. Exposure of blood, offal, and other filth in the vicinity of dwellings. Insufficient water supply. Sewers not ventilated. Privy nuisances.
	" "	Mold urban sanitary authority.	*Mold Urban Sanitary District.*—Persistent presence of typhoid fever. High death-rate from zymotic disease. No provision made for isolation nor disinfection. Very defective drainage. Unwholesome disposal of sewage. Inadequate water supply. Exposure of wells to contamination. Privy nuisances. Pigs kept too near dwellings. Dwellings dilapidated.
ighley and Oakorth. (Yorks.) ulation, 28,059. *Dr. Stevens.*	Regis.-General's Returns	Keighley urban sanitary authority.	*Keighley Urban Sanitary District.*—Watercourse polluted. Defective drainage. Insufficient supply of water. Trade and pig-keeping nuisances. Defective arrangements for excrement and refuse removal. Unwholesome dwellings. Overcrowding. Common lodging-houses ill-regulated.
	" "	Keighley rural sanitary authority.	*Keighley Rural Sanitary District.*—Water supply liable to contamination. Defective drainage. Accumulations of excrement and refuse.
	" "	Oakworth urban sanitary authority.	*Oakworth Urban Sanitary District.*—Defective drainage. Water supply insufficient and liable to contamination. Accumulations of excrement and refuse. Pig-keeping nuisances. Unwholesome dwellings. Polluted open streams.
nton - - (Notts.) opulation, 6,315. *Dr. Thorne.*	Report from Medical Officer of Health.	Lenton urban sanitary authority.	Middensteads in general use; some of which contain enormous accumulations of excrement and refuse. No systematic arrangement for the removal of their contents. Water-closets badly constructed and productive of nuisance.
orfolk and Norwich Hospital. *Mr. Radcliffe.*	Request from governing body.	Special - -	Recent fatal prevalence of pyæmia and erysipelas. Demands upon the hospital have outgrown its accommodation. Means wanted for isolating traumatic infections. Wards insufficiently ventilated. Drainage arrangements faulty. Various structural improvements, and systematic sanitary supervision, wanted.
orthampton General Lunatic Asylum. *Dr. Buchanan.*	Request from Medical Superintendent.	Special - -	Extensive outbreak of enteric fever. Its extension apparently due to the defective state of the drains of the asylum.

Area of Inquiry and Name of Inspector.	Ground of Inquiry.	Jurisdictions Concerned.	Chief Facts reported by the Inspecto
16. Oldbury Registration Sub-district. (Worcestershire.) Population, 17,636. *Dr. Ballard.*	Regis.-General's Returns	Oldbury urban sanitary authority.	*Oldbury Urban District.*—Deaths increasing year by year. Prevale of zymotic diseases. Littl nothing has been done to carry the recommendations made by Thorne on previous inspection 1871. Absence of any proper dra age. Nuisance from accumulati of slops and sewage. Brook co an open sewer and productive of gr nuisance. Privies dilapidated overfull. No proper system for moval of excrement and ref Dwellings dirty, damp, dilapida and unfit for habitation. Scarcity house accommodation. Smoke n sance.
	,, ,,	West Bromwich rural sanitary authority.	*Oldbury Rural District.*—Cotta undrained. Accumulations of s age in neighbourhood of wells houses.
17. Oldham Registration District, parts of: viz.,— The Rural Sanitary District. (Population, 2,467.)	Regis.-General's Return	Oldham rural sanitary authority.	*Oldham.*—Drainage very defect Water supply insufficient. Wells posed to pollution. No systematic rangements for removal of excrem and refuse. Dwellings insufficie ventilated.
Royton Urban Sanitary District. (Lancashire.) (Population, 7,794.) *Dr. Stevens.*	,, ,,	Royton urban sanitary authority.	*Royton.* Epidemic of enteric fe System of sewerage defective. Sew unventilated. Privies dilapida and overfull. Soil and air pollu by overflowing cesspools. No sys of scavenging. Houses badly b insufficiently ventilated, and ou repair. Overcrowding. Enorm masses of excrement deposited the neighbourhood by the Cam Fertilizing Company.
18. Pontefract Registration Sub-district, part of. (Yorks.) (Population, about 2,300.) *Dr. Beard.*	Regis.-General's Return	Pontefract rural sanitary authority.	*South Featherstone.*—Enteric f constantly prevalent. Back to houses in course of erection. Buil not controlled by sanitary authe Houses being built on arches stream which receives sewage. crowding. No means of isol cases of infectious disease. Cess not watertight. Houses gene undrained. Water supply ex to pollution by soakage from pools.
	, ,,		*Street houses.*—Prevalence of en fever. Water supply expose pollution by soakage from cesp
19. Potterspury Registration District. (Northamptonshire.) Population, 11,717. *Dr. Thorne.*	Regis.-General's Returns	Potterspury rural sanitary authority.	Prevalence of enteric fever. *Paulerspury.*—Wells polluted by face soakage. Defective drai Nuisances.
	,, ,,		*Stony Stratford.*—No system of d age. Water supply obtained wells sunk in gravel and expos pollution from cesspool soakage
	,, ,,		*Wolverton.*—Water supply expos risk of pollution by suction o matters from closet pans into of an intermittent service. ventilated sewers. Passage of air into dwellings. Nuisanc sewage outfalls. Offensive mid
	,, ,,		*Wolverton End.*—Parts of the h extremely filthy. Soil sodden water and liquid filth. Much sance.
20. Ramsay Registration Sub-district. (Hunts.) Population, 5,449. *Dr. Airy.*	Regis.-General's Returns	Huntingdon rural sanitary authority. Ramsay urban sanitary authority.	Prevalence of zymotic disease, e ally of enteric fever. Cottage and dilapidated, and rendered by want of proper eaves-gutt and spouting. Canal rendered sive by inflow of sewage. S insufficiently provided with va tion and means for flushing regular system of excremen moval. Nuisance from pig ke No hospital accommodation.

ea of Inquiry and me of Inspector.	Ground of Inquiry.	Jurisdictions Concerned.	Chief Facts reported by the Inspector.
outh Kensington, —one household nd its associations. *Dr. Buchanan.*	Personal information -	Private - -	Outbreak of scarlatina among a number of persons (family and guests) who had fed at the same house; and who, it appeared, might there have consumed an infected article of food. Report subjoined.
wansea Rural Sanitary District, part of. (Glamorgan.) *Mr. Radcliffe.*	Request from local authority.	Swansea rural sanitary authority.	Enteric fever endemic. Overcrowding. Want of ventilation of houses, and especially of the bedrooms. Absence of privy accommodation. Water supply exposed to excremental pollution. Want of drainage in vicinity of houses.
West Riding House of Correction. (Wakefield.) *Dr. Ballard.*	Request from Home Office.	Special - -	Prevalence of enteric fever preceded and accompanied by diarrhœa. Interior of prison polluted by sewer air in consequence of faulty construction of sewers and drains. Infection probably spread by the use of infected earth supplied to earth-closets.
Wednesbury Registration Sub-district. (Staffordshire.) Population, 25,030. *Dr. Ballard.*	Regis.-General's Returns	Wednesbury urban sanitary authority.	High general death-rate, and high mortality from zymotic disease. No proper sewering and drainage. In some parts wells either polluted or water supply wanting altogether. Unwholesome cottages. Close, unwholesome, undrained courts. Insufficient dealing with infectious diseases.
Wells Registration Sub-district. (Norfolk.) Population, 6,473. *Mr. W. H. Power.*	Regis.-General's Return	Walsingham rural sanitary authority.	Outbreak of diphtheria, the origin of which is obscure. Want of proper sewerage and drainage. Great scarcity of drinking water in dry seasons. Dwellings insufficiently ventilated. Medical officer of health not furnished with proper information. No proper inspection of nuisances. No means of isolating cases of infectious diseases.
West Bromwich - (Staffordshire.) Population, 41,795. *Dr. Ballard.*	Regis.-General's Return	West Bromwich urban sanitary authority.	High general rate of mortality. Prevalence of zymotic diseases. District generally unsewered. Large accumulations of excrement and refuse. Scavenging arrangements defective. Polluted wells. Scarcity of drinking water in some places. Damp and dilapidated houses. Scarcity of small houses. Overcrowding. No hospital accommodation for cases of infectious disease.
Wiveliscombe - (Somerset.) Population, 2,059. *Dr. Blaxall.*	Regis.-General's Returns	Wiveliscombe urban sanitary authority.	Prevalence of fever. Many dwellings unfit for habitation. Accumulations of refuse. Pig nuisances. Insufficient privy accommodation. Defective sewerage and drainage. Water supply exposed to pollution.

App. No. 5.

No. 5.

On Enteric Fever at Croydon, by Dr. Buchanan.

Report on an Epidemic of Enteric Fever at Croydon in 1875, by Dr. Buchanan.

Croydon population.

Croydon parish, the area over which the Croydon Local Board of Health has sanitary jurisdiction, forms a part of the Croydon sub-district of the Croydon Registration district. The population-statistics of the various parts of the Registration district are as follows :—

Registration District, Sub-District, Parish, or Place.	Area in Acres.	1861.		1871.		1875.
		Inhabited Houses.	Population.	Inhabited Houses.	Population.	Estimated Population.
Croydon District	32,548	8,073	46,474	14,525	83,853	93,881
Croydon sub-district	20,851	6,309	37,093	12,254	71,319	81,020
Mitcham sub-district	11,697	1,764	9,381	2,271	12,534	12,861
In Croydon sub-district.						
Croydon parish -	9,901	5,338	30,249	9,873	55,652	63,000
Penge hamlet -	770	668	5,015	1,956	13,202	15,500
Coulsdon parish -	4,314	140	993	250	1,591	1,620
Addington „ -	3,605	122	639	121	607	630
Sanderstead, , -	2,261	41	206	54	267	270

Births and Deaths.

In Croydon sub-district during recent years, the births, and the deaths from all causes and from various epidemic diseases, are thus given by the Registrar General :—

Year and Quarter.	Births.	Deaths, all Ages.		Deaths at Houses Registered about the								
		Previous average.	In quarter.	Deaths 0-1[illegible]	Small-pox.	Measles.	Scarlet Fever.	Diphtheria.	Hooping Cough.	Fever.	Diarrhœa.	In Public Institu[illegible]s.
1870 - i	658	307	370	65	—	4	38	—	3	6	2	30
ii	602	290	308	75	1	3	11	1	17	7	4	45
iii	608	310	319	105	2	4	21	—	6	8	43	41
iv	585	294	313	92	8	7	22	2	10	7	8	41
1871 - i	641	331	389	95	32	16	19	—	9	7	1	48
ii	582	312	317	90	30	4	9	—	10	9	16	60
iii	591	339	337	113	7	2	5	1	5	5	48	46
iv	582	309	293	85	—	4	3	—	4	9	11	35
1872 - i	687	360	339	89	3	19	4	3	9	9	6	44
ii	604	309	281	59	—	27	—	1	11	7	—	43
iii	598	333	339	118	1	1	3	—	19	5	32	50
iv	603	310	279	70	—	7	2	2	14	4	4	33
1873 - i	670	366	317	73	5	1	—	3	5	7	6	48
ii	618	302	315	77	—	—	—	1	8	4	1	45
iii	628	332	279	89	—	—	—	3	3	1	44	28
iv	652	296	307	73	—	11	2	1	—	3	7	36

Year and Quarter.	Births.	Deaths, All Ages. Previous average.	Deaths, All Ages. In quarter.	Deaths, 0-1.	Deaths, all Ages, from. Small-pox.	Measles.	Scarlet Fever.	Diphtheria.	Hooping Cough.	Fever.	Diarrhœa.	In Public Institutions.
1874 - i	642	348	337	76	—	15	2	3	7	7	—	34
ii	660	305	330	62	—	44	—	1	7	8	3	42
iii	620	319	303	105	—	12	4	1	8	4	29	35
iv	628	294	357	87	—	1	6	2	11	—	10	44
1875 - i	670	331	448	93	—	—	8	1	12	8	3	62
ii	671	309	379	78	1	—	2	1	13	32	11	43
iii	655	307	359	106	—	—	5	2	15	17	30	46
iv	683	314	437	103	—	—	33	4	11	44	15	48

Fever mortality, 1875.

The registered mortality from fever in 1875 has required certain corrections, on account of persons dying in public institutions, and on other grounds. After such corrections, the fever deaths are found to have been distributed in the two sub-districts respectively as follows :—

In Mitcham sub-district—

4 deaths, being at the rate of 0·32 per 1,000 inhabitants.

In Croydon sub-district—

100 deaths, „ „ 1·24 „ „

Again, within *Croydon sub-district* the distribution was—

In Croydon parish :

90 deaths, being at the rate of 1·42 per 1,000 inhabitants.

In Penge hamlet :

8 deaths, „ „ 0·52 „ „

In Croydon parish :

the two systems of distinctive[illegible] „ 1·24 „ „

In other parishes :

0 deaths, „ „ 0·00 „ „

In Croydon parish, the 90 fever deaths occurred in the several months of the year thus :—

Jan.	0	April -	14	July -	3	Oct. -	15
Feb. -	1	May -	10	Aug. -	4	Nov. -	19
March -	4	June -	7	Sept. -	5	Dec. -	8

Attacks of fever, 1875.

It is in view of such statistics as the above, relating only to mortality, that inquiries of the present sort usually have to proceed. But at Croydon the advantage has been gained of records of fever-sickness, non-fatal as well as fatal. First to the Medical Officer of Health, and afterwards to myself, the medical practitioners of Croydon and its neighbourhood have furnished, at great cost of time and trouble to themselves, a mass of information as to the places and times of fever occurrence. The facts thus given are from their nature of incomparably greater value than those derived from the records of mere deaths, and they have been given with so much completeness that they can be used for investigating the distribution of the fever for the purposes of this report.

Their distribution in Croydon district.

The brunt of the fever-incidence on Croydon district in 1875 has been, as the mortality tables have already shown, upon the parish of Croydon itself. There was a local, but somewhat sustained, epidemic at Penge, apparently not related in any way to the Croydon outbreak. In other

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On Enteric Fever at Croydon, by Dr. Buchanan.

parishes of the Croydon sub-district, and in the Mitcham sub-district, there has been no amount of fever prevalence that can be called an epidemic.

In Croydon parish.

For Croydon parish, the area of the Local Board of Health, 1,164 cases of fever appear on the returns of medical men as having been attended by them in 1875. The returns (owing to the mode of their collection) are not so complete for the months of May to August as for other periods; but they are so nearly perfect that the total number of cases occurring in the parish during the year may be stated to have been about 1,200.

Nature of fever.

The fever has been essentially enteric or "typhoid" fever, with a largish sprinkling of cases of that indefinite complaint which is named "simple continued fever," or else "febricula." In the returns 104 cases are spoken of under some such name. These are included in the 1,164 cases. No case of typhus fever was heard of in the year.

"Febricula," and the like, have been included with the prevalent enteric fever upon a balance of medical considerations, into which it is not necessary here to enter. The inclusion of such cases does not affect the general statements of this report, and when it affects particular statements, the fact will be noted.

Ninety deaths in about 1,200 attacks is about one death to 13 attacks, a mortality about that which is usual when enteric fever occurs in a community of average ages.

Houses attacked.

The 1,164 cases occurred in 959 houses. As there are now 11,526 houses in the parish of Croydon, it follows that 83 per 1,000 houses have been invaded by the disease. Two hundred and five cases were returned from houses that had been already invaded. Apart from public institutions and schools, there were examples of particular houses having in them, not two only, but three, four, five, or six attacks of fever. In most of the study that has been given to the distribution of sickness, the invasion of the house had been regarded as more important than the recurrence of disease in a house, and most of the statements that follow will have reference to houses rather than to individual patients.

Times of attack.

Local medical opinion differs about the existence of enteric fever habitually in Croydon. In view of the death statistics given above, and of the necessarily greater value of positive than of negative opinion on the point, I cannot but think that the disease is seldom wholly absent. It is certain, however, that in the last quarter of 1874 there was very little of it. In that quarter there was no death from any kind of fever.

The 959 houses in Croydon parish that were attacked with fever in 1875, were first attacked in the following months:—

Jan. -	15	April -	186	July* -	18	Oct. -	275
Feb. -	53	May* -	39	Aug.* -	32	Nov. -	92
March -	79	June* -	30	Sept. -	69	Dec. -	71

An asterisk* is here put against the names of those months for which the return are known to be less complete.

Many houses had in them cases of "febricula" as well of enteric fever. They ar dated here according to the first attack of any fever. The largest proportion of suc minor disease was in January, when six houses had in them cases of "simple co tinued fever" or "febricula." For the rest, most of the cases thus named appe in the returns of the last four months of the year.

The above table teaches that enteric fever existed to only small extent in January, but began to assume epidemic proportio in February. It increased somewhat in March, and became a wi epidemic in April. Subsiding for three or four months and r assuming epidemic activity in September, its outbreak in Octob surpassed that of the spring, and it continued abundantly prevalent the end of the year. In the earlier half of the year fever attacked 4

houses, or 35 per 1,000 houses in the parish; in the latter half of the year it newly attacked 557 houses, or 48 per 1,000 houses.

These are the broad facts, themselves for the most part elicited during the inquiry itself, of the epidemic of which I am instructed to investigate the causes. Other facts concerning the local distribution of the epidemic will come under consideration in connexion with questions of causation.

Means of fever-spread.

There is before the Department and the medical profession a vast mass of evidence to the effect that enteric fever habitually spreads through a community by means of the bowel discharges of the sick; something from those discharges finding its way either into the air which people breathe, or into the water or food which they consume. This report will consist essentially in the application of this experience to Croydon, and it will not be concerned with the introduction or other "origin" of the fever.

Croydon sewer systems.

The greater part of the excrement of Croydon parish is discharged into sewers. Of these sewers, the larger number, serving 9,051 houses, converge to an outfall at Beddington, where the sewage is used in irrigation. To the east of the parish other sewers, serving 1,405 houses, converge to the South Norwood sewage farm. These are the distinctively Croydon sewer systems. At the extreme north of the parish 506 houses drain into the Effra sewer system. There remains 564 houses, a few in central parts, but the great majority in the more distant parts of the parish, which have their private drainage arrangements, generally by cesspools, but a few by irrigation within their own precincts.

Distribution of fever.

The distribution of Croydon fever in 1875, in its relation to the sewer systems of the town, has been as follows:—In the houses draining to the Effra sewers, only three cases of fever have been heard of. The houses which have cesspools or private drainage arrangements of their own, are only known to have had six cases of fever in them. The two systems of distinctively Croydon sewers are those on which the fever has mainly fallen. It has not, however, affected them both in the same degree. In the subjoined tabular statement are shown the facts of fever incidence on the houses of the parish, according as the houses are one or the other sewer system.

Sewer System.	Number of Houses.	Number attacked by Fever.	Per 1,000 Houses.	Number with Deaths from Fever.	Per 1,000 Houses.
On Beddington system -	9,051	905	100	83	9·2
On South Norwood system -	1,405	45	32	4	2·8
Not on either system -	1,070	9	8	3	2·8
Parish - -	11,526	959	83	90	7·8

Central incidence.

Within each of the two systems there have been local differences of fever prevalence; and there have also been some broad differences that may be generally stated. The circumferential parts of the parish have suffered less than the central parts on the same sewer system. Thus, Thornton Heath draining to Beddington by a sub-system largely distinct from the general sewer system, has had comparatively little fever. The parts to the north and east of Norwood Junction Station, draining to South Norwood, have almost wholly escaped, but in this direction local outbreaks have pushed out the boundary line of the epidemic. The

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hamlet of Shirley, at the end of another branch of the South Norwood sewers, has also had scarcely any fever. At the south end of the parish about Croham Road, there has been but little of it.

Incidence on high levels.

Houses, to whatever system sewered, situated at the higher levels of the town, have had more fever than those on the lower levels. This accords with general experience in like cases, and is partly, but probably only partly, to be connected with the greater frequency of inside drain communications in better class houses, which commonly find themselves on the higher levels.

On the respective sewer systems.

Cases of fever occurred first on the Beddington sewer system, which was pretty widely, if not intensely, infected before 1875 began. It was not till February 7th that any case is known to have occurred in the houses of the South Norwood system.

The subsequent monthly incidence of the fever on the houses of the Beddington (B.) and South Norwood (S. N.) systems is shown below.

	B.	S.N.		B.	S.N.		B.	S.N.		B.	S.N.
Jan.	15	0	April	176	9	July	18	0	Oct.	159	15
Feb.	48	4	May	34	4	Aug.	32	0	Nov.	83	6
Mar.	74	5	June	30	0	Sept.	68	1	Dec.	68	1

Arrangements of sewers: their size.

The original sewer system of Croydon, constructed in 1851 and following years, was altogether of pipe, and served for excrement, slop-water, and roof-water only. The pipes were of small calibre, nine inches being a common diameter for principal sewers, and six inches and four inches for sub-sewers. Experience showed numerous stoppages occurring in these very small sewers, and as the town grew few public sewers were made of smaller diameter than nine inches, and the smaller sewers of the central parts were from time to time replaced by larger pipes. On the South Norwood system, of altogether more recent formation, no sewer is less than nine inches diameter. Some main sewers and the two chief outfall sewers are now of brick, of a diameter of 24 inches and upwards. In many parts of the town the sewers are on the "back system;" in other parts they run under the public roadway.

Their relation to ground-water and rain.

In the original arrangement of 1851, special provision was made, by means of the Bourne culvert, for keeping the ground-water down to a lower level than previously, and for thus preventing flooding of the lower parts of the town. It was intended that no ground-water or rain water (other than from roofs) should enter the pipe sewers. For some years, too, the pipe sewers received very little surface water, but by degrees it became a not infrequent practice to send into them the drainage of roads. The result was at times to overcharge the smaller pipes, and fresh arrangements have within the last year or two been made for the separate disposal of such surface water as had before been sent to the

Gradients, ventilation, flushing.

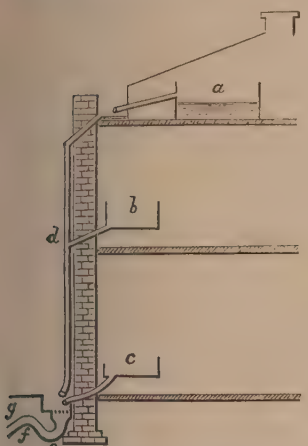
pipe sewers. In some parts of the town the sewers have a very slight incline; in other parts they are very steep. Means of ventilating the public sewers have, since 1854, been provided by shafts in the roadway. The contrivance introduced for flushing the sewers consists of a junction between the water main and the sewer, allowing a considerable quantity of water to be discharged into the sewer upon opening a sluice-cock.

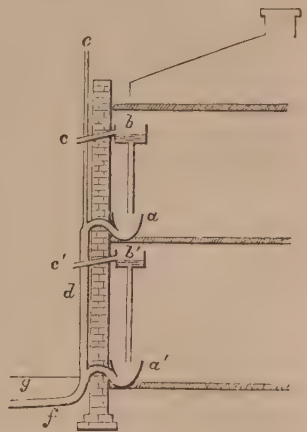
House drainage.

The drainage of houses in Croydon is by 4 and 6-inch pipes in uninterrupted communication with the public sewers. In a very few houses only is there any trap in the horizontal part of the house-drain. Of late years great attention has been given to "disconnecting" sinks, cistern wastes, and bath discharges, and there are many houses where all pipes from such places pass through the outer wall and end at the outside over a trapped

grating leading to the sewer. The watercloset pipes in such houses are habitually more or less ventilated by means of special pipes carried up the house beyond the roof. These serve also to some small extent to give additional ventilation to the public sewers.

The present idea of Croydon house drainage is therefore somewhat according to the following diagrams, of which No. I. shows the pipes disposing of slop and waste, and II. shows the pipes connected with the waterclosets of the house :—





I. *a*. Roof cistern (rarely present).
b. Upstairs sink (bath would be similarly provided).
c. Scullery sink.
d. Rainpipe.
e. Trapping bend under outside grating.

II. *aa'*. Waterclosets.
bb'. Water-waste preventers for closet supply.
cc'. Overflows from same, going into the open.
d. Soilpipe, here shown outside; an approved arrangement.
e. Ventilation pipe.

I. & II. *f*. Junction of slop and soil drains directly continuing to the public sewer.
g. Ground level.

Of course all houses have not these arrangements, and notably the older parts of the town show many departures from what is regarded as the proper system.

Efficiency of sewers.

The efficiency of the system of public sewerage for the complete and rapid removal of excrement seems at first view to be considerable. There is certainly not at Croydon that universal disintegration and decomposition that goes on in the large brick sewers of other towns, for at the Croydon outfalls paper and shaped fæces may be observed among the matters brought down in the sewers. But a very little further examination shows that there are many local defects, and some important general defects, in the Croydon arrangements. Many of the older town sewers remain, some being admittedly unequal to the demands made on them by the growth of the town. In the lower-lying, flatter parts of the town, some sewers are known to be in bad order and to be incapable of being kept clean. The flushing arrangements are not such as to allow of any sewer being thoroughly washed in its whole interior; a 4-inch water stream for example only serves to fill one-fourteenth part of the area of a 15-inch sewer pipe, and can only wash a quarter of its interior circumference. Nor are the public sewers adequately ventilated. Intervals of 120–250 yards may be found between the ventilating shafts in a roadway, such shafts having covers that much reduce this available opening, and being in addition often blocked by trays of charcoal. The

Church Road outfall sewer has no ventilator between a point just at its end, and a point (in the town) half a mile before its end. If this outfall sewer should ever run full, the air in the Church Road sewer would certainly be very dangerously confined.

Efficiency of house drains.

The efficiency of the drainage arrangements of particular houses in Croydon, is, also, at first sight, considerable ; as was to be expected in a town where a really large proportion of the residents take an interest in sanitary matters. Grosser drain-defects, such as untrapped drains, bath and sink wastes going directly into sewers, and drains leaking about the basements of houses are, it is true, sometimes met with both in good-class houses and in houses of the poorer class. But the drainage defects in good-class houses are commonly of a less obvious kind than these, consisting of hidden cracks in pipes, overflow pipes going into soil pipes, ventilation pipes zigzagged so as to prevent any air current through them, or opening near to some window. In poorer houses, where all closets are outside and all sinks disconnected, the closet drain is sometimes found to have a fracture in it, or the outside gully to be untrapped.

Relation of sewer and drain defects to fever.

In the course of my inquiry I examined a large number of houses—of course not a large proportion of the whole, but in a variety of respects typical of the whole—including many where there had been no fever, as well as those where there had been fever, among the latter a probably large proportion where the circumstances of fever production had been most obscure; and I satisfied myself that in a very considerable majority of the Croydon houses that have had fever, drain air charged with infection from the common sewers of the town had had the opportunity of entering the houses. Oftentimes in a group of houses, resembling each other in their general sanitary arrangements, some particular drain defect was discoverable in certain houses but not in others ; and as often it was found that the incidence of the fever had been upon those which showed that drain defect and not upon the houses which did not show it.

I quote from among other instances two examples of such differentiation. They were cases of a less common kind, where the relation of the fever to the particular defect had not been at once obvious.

(1.) There had been fever at some houses in St. Peter's Street, with no inside drains whatever, with outside waterclosets and disconnected scullery sinks. The first seven of them were visited, and it was found that the drain just outside the house was at four of them practically untrapped, but was efficiently trapped at the other three. In none of the latter had there been fever, but this disease was present last year in three out of the four former. (2.) Howard and Birchanger Roads, South Norwood, were visited because of a different prevalence of fever in the two. Thirteen houses in the former road, including seven that had had fever, were examined, and eight houses in the latter, including one of two that had had fever. Few of the houses were found with their drainage arrangements conforming in all respects to the standard ; but one particular defect characterised the great majority of those where there had been fever. This was an overflow pipe going direct into the sewer from a cistern that was usually placed in a very confined situation under a bedroom floor. In the Howard road this arrangement was seen in eight houses, the cistern furnishing more or less of the drinking-water in the case of seven of them, and in six out of these seven there had been fever. It was not seen in the five other houses, only one of which (having a stinking watercloset) had had fever. In the Birchanger Road this particular defect was witnessed in two houses only out of the eight visited, and one of the two had had a case of fever; the houses where there was no such arrangement had escaped. [Facts as to the second fever house were not obtainable.]

Other ways, less direct than the foregoing, by which excremental products bearing with them the contagium of enteric fever have produced the disease, will immediately come under review. But there can, I think, be no doubt that the chief way in which enteric fever spread last year in Croydon was the most direct and commonplace way of all, viz., by the escape of infected air from the sewers and its inhalation by persons susceptible of the disease.

Intensity of outbreak.

The great intensity and simultaneousness of the fever epidemic over Croydon should be no hindrance to the acceptance of this view. Where sewers are small and ill ventilated they constitute perfectly sufficient means for the rapid distribution of fever infection; and places having such sewers may not only show fever rates maintained as high as before the sewers were made, but they may show as smart outbursts of fever as are witnessed where conveyance through water or milk is in question. Croydon itself, after it had made its sewers and before it attempted to ventilate them, had this experience. So other instances that have come under my personal knowledge, fever has maintained itself after pipe sewers, ill ventilated, had been laid: as Rugby, in Carlisle, in Chelmsford, in Penzance, in Worthing; in the last two places breaking out in severe, sudden, and diffused epidemics without there being any question of other distribution than by sewers. And my personal experience is confirmed by that of others. Towns with larger sewers have not appeared to have the same suddenness of outbreak when spread by means of sewer air has been in question. In them the evil influence of sewer infection is more gradually manifested, as might be expected from the different physical circumstances of the two kinds of sewers.

The intention of small sewers, as opposed to large ones, is that their contents shall flow away with great rapidity, leaving the sewer clean and free from deposit. So far as small sewers fail to fulfil this intention, they have certain disadvantages of their own. To some extent when sewers are running freely, but greatly more when they are not running freely, displacement of air from them is an affair of sewer calibre. If a 6-inch sewer be not running well, and a pail of water be thrown into it, that water will occupy 16 times the space, relatively to the sewer diameter, that it would occupy in a 2-feet sewer; displacement of air in the smaller sewer will be relatively 16 times as great, and the displacement will be greatly more sudden. Hence the air in a small sewer is liable to be under far greater pressure than the air of a large sewer. To afford a safe exit to displaced and compressed sewer air is one (the more popularly understood) object of sewer ventilation; and it is plain that means of such ventilation are wanted more numerously in proportion as the displacements of air may be local and sudden. For any want of perfect freedom of current and lack of proper exit-means for displaced air *tells for more* in small than in large sewers.

But at least as important a further object to be attained by the ventilation of sewers, is such dilution of sewer air as shall reduce to the utmost its harmful qualities. These harmful qualities are popularly measured by smell, and if there be no sewer-smell people think little of danger from a sewer. The popular view may be true enough of such minor harm as may come from ordinary excrement decomposition; but it is certainly not true of such greater harm as comes from the specific infection of a sewer. Croydon itself has given some of the experience upon which this judgment is founded. In those of its former fever epidemics which could be indisputably associated with escape of sewer air into houses, the offensiveness of the sewer air has not been great, nothing nearly so great as at many a harmless street gully in London. It has even happened at Croydon and elsewhere that noise and not smell has been the means by which the escape of infected sewer air has been recognised. And increasing knowledge of the nature of fever has made it pretty certain that the material of contagion is a substance itself without odour, and perhaps less likely to be active in excrement that has passed into fœtid decomposition.

Thorough ventilation, then, for the purpose of diluting and as far as

possible nullifying the infection that infective sewage exhales, is wanted equally whether the sewer stinks or does not stink. Want of due distinction between stink and infectiveness has led to this consideration being overlooked in practice; and it has repeatedly happened that the air of small sewers has possessed (to judge by results) an infectiveness more intense than the air of more offensive large sewers. The air in a 9-inch pipe, with petty openings at every 150–250 yards, and no other openings, except the soil pipes of houses, is liable, it appears to me, to contain in a very concentrated form the poison of enteric fever, if excrement from fever patients be discharged into the pipe anywhere in the neighbourhood.

Sewer-air "laid on" to houses.

While I admit that for the most part the sewers of Croydon are well adapted for the removal of liquids and solids, they appear to me to be adapted, when infected by fever excrement, to facilitate the passage of infection into the vicinity of houses. The air of the sewers is, as it were, "laid on" to houses; it is arranged that every house drain and every house soil pipe shall contain, up to the very wall of the house and up to the very trap of the watercloset, the common air of the Croydon sewers, not simply charged with impurities it may receive from the particular house, but charged also with any dangerous quality that it may have brought from other houses; for hardly anywhere in Croydon can there be found an arrangement for severing the sewer air from the air of the house drain. So that, wherever drain air has entered a house, no matter by how inconspicuous a defect, and no matter whether it has given rise to stink or not, it has been the air of the common sewer, and this was throughout 1875 charged to an intense degree with the infection of enteric fever.

It were to be wished that, at this point, before passing to consideration of other ways by which enteric fever may have spread in Croydon, some kind of estimate could be formed of the extent to which its spread has been in the commonplace direct way that has heretofore been considered. This is not, however, possible, for two reasons; first, that if sewer infection have been so intense yet so inappreciable by the senses as it doubtless has been, many persons besides those who received it through discoverable house defects must have become exposed to it; secondly, and conversely, that it cannot certainly be affirmed in regard of those persons who had the opportunity of breathing infected air, that there was no other way in which infection was presented to them. It will be needful to put out the whole history before attempting to affirm the shares that various conditions have had in producing the epidemic.

Other means of fever-spread.

There now arise for consideration other methods, by which the material of enteric fever may have been distributed among the population of Croydon, namely, by means of milk or of water.

By milk?

Suggestion that fever may have been spread by means of milk has come essentially from those who doubt the wholesomeness of sewage-farm milk, and of milk from cows fed on sewage produce. Inquiry as to the milk supply of fever-infected houses, first by the medical officer of health, and afterwards independently by myself, has, however, shown no ground for suspecting that milk has played any part in the epidemic.

To the houses which I myself visited the milk supply had been furnished not by one or two, but by 18 milkmen, and there was no special incidence of fever on the customers of any one of them. Of the 18 milkmen, some got milk or fodder from the sewage farm, others got none. There was some difference of fever incidence on the customers

of the two classes, a difference probably unimportant as the inquiry was not on a large scale, but the direction of the difference was in favour of the customers of those milkmen who had dealings with the farm.

By water?

As regards influence of water, there is reason to believe that polluted water has played some part in the phenomena of the epidemic. A very large part of the time that has been spent on this inquiry has been taken up with endeavours to understand the extent to which water can have operated to spread infection, and the method of such operation. The facts and conclusions will, however, be reported as briefly as possible.

The primâ facie case against water as an element in the production of fever is as follows :—

1. Impurities are known to have entered the wells and reservoirs.
2. Impure water has been known to be drawn from house taps.
3. The area supplied by Croydon water has had much more fever than other areas of the parish, thus :—

Water System.	Number of Houses.	Number attacked by Fever.	Per 1,000 Houses.	Number with Deaths from Fever.	Per 1,000 Houses.
On Croydon* system	9,039	942	104	83	9·1
Not on Croydon system -	2,487	17	7	7	2·8
Parish -	11,526	959	83	90	7·8

4. In the South Norwood neighbourhood there have been local outbursts of fever just within the Croydon water area, and no such outbursts beyond that area.

5. Within the town, some cases of fever have occurred in houses served by Croydon water, though the drainage arrangements of the houses appeared perfect, and in some houses though the drainage was disposed of independently altogether of Croydon sewers.

Impurity in wells.

Referring for an account of the principal impurities that have obtained access to the Croydon wells to a memorandum (appended Note B.) which I have already written on the circumstances of those wells, I observe that any minor sources of impurities in the water of the wells, beyond those there described, have been wholly unimportant in the present relation. As regards any influence upon the production of fever of the impurities reported in the appended paper it has to be noted, first, concerning their amount, that the whole population of Croydon parish, each person drinking a gallon of water daily, would not in four years have got through one grain of the "albumenoid ammonia," which had been contributed to the town water supply from the topmost thirty feet of gravel and chalk ; secondly, concerning their origin, that the sources of impurity were certainly local and all of them pretty certainly known ; and thirdly, as to their nature, that none of the ascertained sources of impurity are suspected of having been infected with the material of enteric fever. I judge, therefore, that there is no evidence of the well water having been a vehicle of fever contagium.

* With the houses on the Croydon water system are included 240 within the water area and nominally having no water at all or getting it from private sources. As there are very few private wells, and as most of the residents in these houses must drink Croydon water, and also for the sake of brevity, these houses are included with those on the water system of the town. There have been some cases of fever in them, but how many is not known.

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An accomplished member of the local board, taking a wider view, has propounded the theory that epidemics of fever in Croydon, the recent one included, are produced by some fever poison, which he believes to pass from superficial strata into the deep water of the chalk and to be thence distributed in the general water supply, during seasons of exceptionally high or exceptionally low rainfall. I have been unable to follow the arguments by which it is thought to reach this conclusion, and I do not pretend to state them here. But for purposes of reference in this connexion, I think right to extract, from the Memoirs of the Geological Survey, an account of the strata passed through in sinking the old and the new well at Croydon. I also show in a table and diagram, the relation between past fever-mortality and yearly rainfall. These will be found in an appended note (D).

Impurity at reservoirs.

As for impurities having access to the water at the reservoirs, they consist in foul air that may have come up imperfectly disconnected overflow pipes. No importance whatever can be attached to them. The overflows have been properly disconnected while the epidemic has been in progress.

Chemistry of general water supply.

Before reaching this point, I have not considered the affirmative evidence tendered by chemistry in favour of the Croydon well waters; for, undoubtedly, chemistry cannot identify the contagium of fever, and is hardly competent to rebut any positive presumption that on other grounds may have existed against water as a vehicle of fever. But the purity or impurity of water, as it can be told by the chemist, is at least a very important element in the whole question of the relation of water to disease. Now, every chemist to whom the Croydon well water has been submitted speaks of it as a water of the most pure class; and repeated analyses show a constancy in its elements that is a further important evidence of its goodness. It may, in fact, be said that the water, as it leaves the Croydon wells, is, from the chemist's view-point, as pure and as constantly pure as any water need be.

A recent analysis, one of many made by Dr. Dupré for the purposes of this report, gives the following. The specimen was taken from the "arterial main" in Park Lane at 4.20 a.m. on February 13th, 1876:—

Appearance	Clean.
Colour	Colourless.
Taste	Tasteless.
Smell	Inodorous.
Deposit	Very minute trace.
Nitrous acid	None.
Phosphoric acid	Trace.
Metallic impurities	None.
Hardness before boiling	16·3°.
„ after boiling	2·8°.

A Gallon of Water contains	*Grains.*
Oxygen aborbed from permanganate	·004
Total dry residue	21·70
Consisting of volatile matters	1·54
„ fixed salts	20·16
Chlorine	1·01
Nitric acid (N_2O_5)	1·36
Ammonia	0·0007
Albumenoid ammonia	0·0014

A hundred Cubic Inches of Water contain	*Cubic Inches.*
Uncombined carbonic acid	0·56
Oxygen	0·83
Nitrogen	1·78
Sulphuretted hydrogen	None.

Impurity in house services.

Turning to the evidence of impure water being drawn from house taps. I have records of about 40 houses, where this has occurred, all of them within the area supplied with Croydon water. Some 10 of these instances have been merely affairs of cisterns, a small cistern in a confined situation having a waste pipe in direct connexion with a sewer. The most notable case of this sort has already been mentioned in connexion with house drainage arrangements. But in 29 of these instances it was the water drawn from the Croydon water mains that smelt offensively. Some of these cases were learned of by direct inquiry, others by spontaneous communication to the health authority or myself. These cases were scattered up and down Croydon, mostly in single houses, but in one place near South Norwood, of which more particular mention will be made, in a group of houses. The occurrence of bad smell had usually been on one or two occasions only. The following is an example of a not unfrequent communication to the health officer: "In reply to yours of the 15th instant (May 1875), "it is true that one of my children complained of the bad smell and "taste of the water about the time the supply was last curtailed, but "whether her subsequent fever was attributable to the water I cannot "of course say, though we suspect it."

At South Norwood.

The South Norwood case has been the subject of much public comment, but the facts concerning it were not understood in their right proportions until house to house inquiry was made in the locality. A part of the Selhurst road and the Cargreen and Lawrence roads are in question.—In the former there are 40 inhabited houses, 19 on the east side of the way, 21 on the west. Of the 19, no less than eight had fever in 1875, some of them more than once during the year. Of the 21, only two had had illness, and in neither case did the medical attendant believe it was fever. All the 19, and seventeen of the 21, are supplied by Croydon water. In the 19 houses of the east side of the road there was no connexion to be discovered between drainage defects and fever incidence on particular houses; moreover, some of the fever was in houses draining to one public sewer, some was in houses draining to a wholly different sewer. There was no question of cisterns. But there was the peculiarity in house after house of this series, and notably in the houses that had had fever, that the servants had at times, generally at early morning, perceived a bad smell to come from the water taps or from the water furnished by them. This was heard of far more in this group of houses than anywhere else in the course of the present inquiry, and the fact is independent of any view that may be taken of the mechanism of the water-fouling. I failed, it is true, to procure for myself a specimen of the foul water, but it seemed to me impossible not to accept the evidence of the servants, and equally impossible not to connect the ill smell with the otherwise unexplained prevalence of fever.—In the Cargreen and Lawrence roads, there are 13 houses, seven supplied from the Lambeth works, six with Croydon water. Fever has invaded three of the latter, but there has been no definite case in those supplied by Lambeth. In two of the three infected houses (the fact is not known as to the third) there had been some risk to water in cisterns. But bad smell of water as it came from the mains was heard of at one house, where it had been frequently noticed, and was known to the children as being "like onions." I had certain samples of water from these roads collected before 6 o'clock a.m. on February 12th, one from the public main in the street, two from a house where there was a leaking service-pipe and where there had been fever, and two from the house wherein the smell had been observed. Dr. Dupré has examined these five samples, with the result of finding them practically identical with the

sample drawn on the same morning from the arterial main at Park Lane, near the Croydon works. Dr. Dupré found no smell in the samples sent to him, and in his results there is nothing to suggest a reason for any offensive smell. (See appended Note C.)

In the Birchanger road, also in the South Norwood direction, ill smelling water was again heard of, but here it was in houses that had not had fever. A sample of water from a main tap in a house of this road was collected for me in two bottles by the householder, on Sunday February 13th, under the circumstances which he thus notes:—"At "3 p.m. the water was rather bad, when I filled a bottle; but on "putting some water in the other I found it better. Therefore I waited, "and at 5 p.m. I happened to use the tap and found the water very bad, "upon which I emptied the former bottle and filled both afresh, fastened "them immediately and put a label on." "At the time the smell was very "strong and disagreeable, and so was the taste. When drawn the water "continued to run from the tap for two or three hours later much in the "same state. . . . The odour was like that of common gas, and per-"ceptible throughout the room it was taken out of; the taste was most "nauseous." This sample, when examined by Dr. Dupré proved to have neither taste nor smell, [it did not reach him for three days after collection,] and to differ in no notable respect from the sample of which an analysis has been given above. (Note C.) Hereon Dr. Dupré observes, "I have heard of a case where a water pipe became filled with "gas to such a degree that when the tap was opened the gas could "actually be lighted. The nose is, however, the only means we have of "detecting the gas in ordinary cases and no chemical tests would enable "us satisfactorily to prove its presence. I invariably examine both taste "and smell of every sample of water I analyse, and this sample certainly "had neither taste nor smell when it came into my hands. What was "smelt was probably more the air coming out of the tap than the water "itself." Dr. Dupré continues, in anticipation of some opinions to the "same effect that I shall have to express, "The point, however, seems to "me of very considerable importance, more particularly if it has been "observed in several parts of the town, since it shows that there are "leakages either in the main or branch pipes. Now we cannot assume "that such leakages exist only in places where there is also a leakage of "gas near; and the possibility, if not the probability, of sewage finding its "way into the water-supply is thus indicated. The point seems to me "well worth careful examination."

Putting all this South Norwood story together, it seems to me beyond doubt that a variety of local conditions for water contamination have been in operation, some probably leading to coal-gas entering the pipes, others leading to sewer-air or sewage entering the pipes. They are conditions that would be operative chiefly, if not essentially, on the Croydon water, and their occurrence here has had the effect of making that water contrast in a measure with the Lambeth water supply, which is not consumed direct from the main. There is nothing in the facts, however, to suggest that the contamination is due to other than local causes, or that the contrast is between the total water supply of Lambeth, and the total water supply of Croydon.

At a School.

Cases of fever, apparently related to water impurity, have occurred in a large school in the centre of Croydon, and have been the subject of repeated skilled inquiry. The school is on a branch of the low-level water system. It has one wing for 60 boys, another for 40 girls, and a central house for the master's family and the teaching staff. On February 2nd, 1875, soon after reassembling of the school after holidays, a boy fell ill with enteric fever, and the following cases after-

wards occurred :—March 29th, two boys ; April 3rd, one boy; April 11th, one boy and one girl, and a child of the master ; April 25th, 26th, and May 1st, one boy at each date. There was then a break in the disease, and during this break the school vacation. On August 13th, fourteen days after return to school, another boy was attacked, and again there was an interval before other fever occurred. But on October 13th and 15th two more boys were attacked, and on October 14th a female teacher. Other cases, all among boys, happened in succession on October 18th, 19th, 21st, 24th, and 26th, and a case in a male teacher on October 23rd.

The first case of fever, then, may have been an imported one. It afterwards had a special incidence on the boys, and it occurred as two epidemics at the very times when the disease was most prevalent in the town. The occurrences have been in all ways worth studying from the point of view of the general epidemic as well as in the interests of the school itself. All who have investigated it have come to the same conclusion about it, namely, that contaminated water has probably been the vehicle of infection.

The sewers into which the drains of the school discharge have doubtless, since February, 1875, been infected with enteric fever. These sewers are not altogether the same for the boys' department and for the other departments of the school, and the drains themselves have not been quite perfect. But the difference of sewers and the defects of drainage have not been such as to suggest that the infection of fever has entered by this way into the school. Mere infection of particular closets obviously does not account for the outbreaks.

The water service of the several parts of the house and some occurrences connected with it are more suggestively related to the fever. The boys' wing and the master's house are supplied direct from taps on the town main, whereas the girls' school has a large cistern where the water is stored. In March 1875, at the period when the town water supply was exceptionally intermittent, it was twice observed that foul air came from the water pipes in the boys' lavatory. "Here's a jolly stink!" one of the boys was heard to say while waiting to wash in the morning, "we shall be having the water come now." This was some ten days before the first indigenous case of fever in the school ; so that great interest attaches to the source of the foul air. It is to be noted that if that foulness did mischief, it was necessarily upon the boys that it would have most operated. The boys were waiting for their water, and got the first of what came into the school. The master's house would not get its water till the pipes had been emptied of their first contents ; and the girls' cistern was filled with water of the previous day. Many experiments were made during the present inquiry to ascertain the conditions under which foreign matters could be introduced into the water pipes of the school ; but, either because the relations of a neighbouring drain to the water main had been altered, or because a leaky water valve hard by disturbed the experiments, or for some other reason, no suction into the school water pipes could be effected. But this much was learned from experiment : That when foreign matter (a pint of Condy) was actually put into the water main supplying the school, it was primarily and in far greatest quantity delivered to the boys' lavatory when the conditions of March last were, as near as they could be, experimentally repeated ; but little was delivered through the house tap, and no appreciable quantity through the pipe supplying the girls' cistern. Hence, if last year any infective matter had entered the water main or the main service of the school, its distribution would have been exactly the distribution of the fever.

The history, however, is plainly that of contamination in a local service,

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not of unwholesome quality in the total water supply of the town. The local contamination moreover appears to have been occasional only. It deserves mention that Dr. Letheby, who investigated the sanitary circumstances of the school on November 6th, submitted a sample of the water to analysis, and could not discover any organic impurity in it.

At Shirley.

A curious instance of apparent contamination of water in its course through pipes comes from Shirley. In a paper published by the Local Board of Health on January 28th, 1876, are given the results of some analyses by Mr. Wanklyn of water from the three wells of the Croydon Waterworks, taken on January 13th, 1876, and the results of an analysis by Mr. Wigner of water from the mains of the Croydon Waterworks, taken at Shirley on January 3rd, 1876. It was taken about 9 a.m. from a tap coming direct from the main in the larder of a private house. There is found to be considerable and significant difference between the well-waters and that of the Shirley house-main.

Translated into common denominations, the four elements that were determined for all four samples compare as follows:—

Sample.	Grains per Gallon.		Parts per Million.	
	Solids.	Chlorine.	Free Ammonia.	Albumenoid Ammonia.
From New Well -	22·0	1·1	0·00	0·02
From Old Well -	20·0	1·1	0·00	0·02
From Pumping Well -	22·0	1·1	0·00	0·02
From Shirley house-main	25·53	1·28	0·12	0·38

As the Croydon well waters are, within very trivial limits, constant in composition, it cannot be supposed that the above differences arise from the different dates of collection. Nor are the differences of such a nature or degree as to be explicable on the assumption that they arise from differing methods of the two analysts. And if there really be the amount here indicated of difference between the water of the Croydon wells, and the same water delivered at Shirley, it follows that the water has undergone very serious contamination in its course to the house whence the sample was taken.

Other instances of contamination in pipes.

All these experiences combine into what seems to me a considerable body of evidence to prove multiple local contaminations in parts of the Croydon water service. Nor is the foregoing the only evidence of foreign matters entering the water pipes. During my visit, for experiment's sake, a common house tap was connected with a pan containing solution of burnt sugar, enough to colour some thousand gallons. On the ordinary night-intermission of supply, the whole of this was straightway sucked into the pipes; and except from one neighbour, was no more heard of. It is on record that a few years ago bloody water came from the main tap of a house next to a slaughter-house. In many parts of Croydon it is a matter of every day occurrence to find common air in the water pipes, showing itself as an effervescence which does not pass off for nearly a minute after the water is drawn into a glass. Water thus sparkling is often talked of as "milky," and it may have been this appearance that led a householder this year to report "soapsuds" coming from his tap. This air probably enters for the most part through special openings provided on certain mains for the express purpose of allowing its entry; but there would seem to be no guarantee that the indraught which in one place allows

of air entering at these defined openings shall not at other places lead to the introduction of injurious matters through accidental openings.

Mechanism of this contamination.

The evidence here adduced respecting the entry of foreign matters into Croydon water pipes is independent of any view that may be taken as to the mechanism of their entry. Of this mechanism it is difficult for me to speak with any confidence, inasmuch as, even to engineers, the physical conditions of the passage of liquids along tubes are not universally known. It is clear that at Croydon there are some very awkward relations between sewers and drains on the one hand and water pipes on the other. First, the valves through which the sewers are flushed are direct openings from water mains closed by a diaphragm that is liable to leak, and through which it is, to say the least, conceivable that matters may pass from the sewer into the water pipe on occasions when the water-service intermits. Secondly, the branch mains in particular streets, and still more often the service pipes of particular houses, sometimes lie in the same trench with sewers or house drains: and it is suspected that in places both may be leaking. Thirdly, hundreds of waterclosets are served direct from water mains by mere taps on the service-pipes without any interposition of cistern or other safeguard. During times of full water pressure in the pipes these communications may not be hazardous; though, as pressure may be taken off a water pipe by making an opening at the farther end of the pipe even more efficiently than by a partial closing of the calibre of the pipe, and as the object of these pipes is to have their farther ends opened, there is little safety in this consideration. It is no doubt mainly at times of intermission of water service that there arise the physical conditions under which suction of matters from without may take place into the water pipes, but I have no reason to believe that such accident can take place only at those times. Some details on these subjects, that, to me at least, are new, will be given in an appended note (E. 1.).

Intermissions of water service.

It is interesting to note the coincidence of intermissions of the public water service with the prevalence of fever in Croydon.

The intermissions were different on the high and low level services of water. The latter (supplying an area in which are 8,403 houses) was cut off during four to six hours, for seven not consecutive nights of January; during eight hours on February 14th; for three hours in the early morning of March 9th, and then, for repairs to the engine, during the greater part of each day of March 16th–23rd inclusive; after which, with one small exception on April 10th, the service was constant up to May 24th. These intermissions, and especially the long ones in the later part of March, afforded opportunities of a kind that must have greatly facilitated the local entry of various matters into the water pipes. The great increment of fever that occurred at the end of March and in early April was significantly related to these intermissions. After May 24th, fresh intermissions in this service occurred for two or three up to five hours on 12 nights of June; for one or two hours on 17 nights of July; for one or two hours on 24 nights in August, for two hours nightly on 19 occasions in September, and the same on 13 occasions in October. Only twice in November was the low-service supply intermitted, but it was off about every alternate day in December. So far as short intermissions of the low service can have assisted in the admission of infected matters into the pipes of that service, the opportunity of mischief arising by that means was, then, afforded during most months of the year, and so far as this consideration is concerned with the fever, the persistence of the fever is to that extent explained. But these considerations give no help to understanding the fresh increase of fever that in September began, and in October culminated in the area supplied by the low service.—The special high-level service (supplying areas in which are 636 houses besides giving a partial supply to cisterns in 272 other houses that are on the low service) was in the first half of the year constantly on in the day-time, but for five hours nightly the high-service

mains were charged with low-service water. When the low service was intermitt during these particular five hours the high service also was off. And March 16–23 there was notable interruption of this as of the other servic After July 15th, it became the custom to keep the proper high-level service all night, and this custom has since been observed, except for two hours August 19, for one hour in the morning and two hours a and half in the afte noon on September 16th, and for three hours on October 28th, on whi occasions the mains were charged with low-service water. It would see therefore, that within the high-service area as in the low-service area, there some suggestion of relation between the early intermissions of 1875 and t growth of fever in the first part of the year; but there is no relation perceptib between the later dates of intermission and the recrudescence and maintenan of fever in the high-service area in the second part of the year.

In short, it appears to me that while conditions of intermitte service are those which specially facilitate the entry of foreign matte into water pipes, it would be a serious mistake to assume that suc matters cannot enter the pipes except during periods of intermissio The evidence from Birchanger Road seems to be of importance in th aspect. As has already been said, reduction or removal of pressu within pipes may be quite as well effected by opening the discharg end of the pipe as by reducing the amount of water flowing throug the pipe; and that water pipes should often have their discharge-en opened is of course a universal liability of their existence. The lesso to be learned from all these considerations obviously is t a order t obtain assurance that the water in pipes shall not becom tangerousl contaminated whenever the pipes happen to leak, it is cessary tha water pipes should everywhere be kept away from all relations wit sewers and drains.

Relation of fever to foul water in pipes.

As regards the extent to which befoulment of water in pipes ma have operated in the distribution of fever in 1875, I find it impossibl to express any opinion. There have been not a few occurrences o fever not otherwise intelligible, which may probably be explained b this befoulment. And it may be that other fever occurrences in place where ordinary sewer defects were observable, have also had to do wit entry of infected material into water pipes.

Incidence on water area.

I have next to consider the meaning of the very special incidence o fever upon the Croydon water area, a fact which I learned early i the inquiry, and of which I have only gradually appreciated the sig nificance. Comparison of the tables on pp. 43, 49, and 60 will show tha the fever affected a larger proportion of houses within the water are than it affected within the distinctively sewer areas of Croydon. Th annexed diagram shows the relation of the two areas, and roughl the chief incidences of fever. It will be seen that the water area is with an exception to which particular reference will be made, wholl within the two sewer areas.

Now if within a larger area infected with fever by a know means, there be a smaller area more intensely infected with feve that fact may be due to one or two or all of three things: the know means of fever production may be more intense in the smaller area; o it may have more special opportunities for operating within that area or there may be a further and independent means of fever dissemi nation in the smaller area. The circumstance of the smaller area being defined in a particular way must not be allowed to obscure these genera considerations, or to raise a presumption that the particular way o definition indicates a new means of spread.

CROYDON.

Scale not quite an inch to a mile.

DIAGRAM OF CROYDON PARISH SHOWING

Most inhabited parts.....

Water area.....

Boundaries of Sewer areas.....

Fever prevalence.....

To illustrate this position from the experience of Croydon itself, I ve examined the incidence of recent fever within the areas respec- ely supplied by the Croydon and by the Crystal Palace Gas Com- nies; and I place the results side by side with the corresponding ures for the sewer areas and for the water areas. The Croydon gas a is, like the Croydon water area, a part of the larger area served by e distinctively Croydon sewers.

Houses attacked by Fever in 1875, classified according to area of service.

Nature of Service.	Per 1,000 Houses in special Croydon area.	Per 1,000 Houses beyond special Croydon area.
wer - - -	91	8
ater - - -	104	7
s - - -	103	13

Now from this consideration of distribution, taken alone, no one ould think of accusing the Croydon gas of being concerned in the oduction of fever. It would at once be perceived that better known asons for the difference of fever prevalence within and beyond the gas ea would have to be investigated ; and that independent reason must given for believing in the competence of gas to act as a vehicle for ver.

To revert :—There is in fact reason to believe that sewer influences as ch have operated more on the central than on the circumferential rts of Croydon sewer areas, just as such influences have often acted ost on the central parts of other towns ; and at Croydon this intenser eration has necessarily been within the water area, since the water ea comprises the more central parts. There is, secondly, reason to lieve that within the water area of Croydon there have been oppor- nities for the passage of infection from sewers into small confined sterns, and into water pipes, opportunities that would be greater under e particular circumstances of the Croydon water service than under ose of the other water services of the parish. I see no reason, in the cts of the fever distribution, to infer that there has been any further dependent means of fever spread within the water area as such.

As regards the fact that in the South Norwood neighbourhood there ve been local outbursts of fever just within the Croydon water area, d no such outbursts beyond it, I have already considered the sanitary rcumstances of the houses where those outbursts occurred, and I have en reason for associating them with impurity in the water services to ose houses. I have now to observe that (as the above diagram shows) e epidemic prevalence of fever has not reached the boundary of the ater area except at South Norwood; that parts of Thornton Heath the north, and parts about the Croham Road to the south, all supplied om the general Croydon service, have (as before mentioned) been but tle attacked. In fact the restriction of fever to central parts has been itnessed within the smaller water area itself.

Fever at boundary of water area.

I have made mention of one exception to the general inclusion of the ater area within the Croydon sewer areas. It is the hamlet of Waddon

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where drainage is into cesspools, or by other arrangements independent of Croydon sewers. To this exception one naturally turns when question is raised about the influence of the general water supply. Unfortunately, the number of houses available for an answer is small, only 33 in the village receiving their supply from the Croydon wells. There has, however, been no case of fever in any of these houses.

Argument from good drainage of some fever houses.

I have little more to say about the presumption that is created against water by the circumstance that some houses with perfect drainage arrangements have had cases of fever in them. In several such houses the presumption was supported by the experience that ill-smelling water had been at some time delivered to the house, or to some immediate adjacent house. In other such houses the fever-cause had probably been operative beyond the house precincts. In others, again, no opinion about the means of fever reception could be formed. These last instances were not numerous, and their occurrence is not surprising if the infection of the general sewer systems of the town was as intense, yet so unrecognisable to the senses, as it is believed to have been.

Summary as to water-influence.

To sum up the water question:—There is much reason to believe that impurities often get into Croydon water pipes, and that in the course of last year these impurities have been instrumental in spreading enteric fever. Although it is impossible to guess at the number of instances in which fever may have been thus spread, it is judged upon a review of the whole history, that water pollution played a much less considerable part than was played by infection delivered from sewers directly into the air of houses. I fail to find any evidence to support the view that the general water supply as it leaves the wells and reservoirs of the town has been at fault.

Recent action of sanitary authority.

Except perhaps in the view here taken respecting the relative amount and directness of operation of one and another condition in the production of fever, there is, I believe, nothing in this report that will be new to the Local Authority, or to its sanitary advisers. That authority has already, during the progress of the epidemic, taken action in several useful directions. It has taken a step for improving sewer ventilation by removing the trays of charcoal from the air shafts of the public sewers. Under the advice of its officer of health, it is taking such steps as are immediately possible for the completer washing and disinfection of its sewers; it has ordered the removal of the "flushing valves" that formed direct connexion between water and sewer pipes; and it has taken measures for preventing leakage of superficial water into its wells.

There will remain a number of other improvements to be made for the removal of conditions that are held to have brought about the recent epidemic:—

First: all public sewers that are not in good order, or are unequal to their work, must, as rapidly as possible, be replaced by perfect sewers.

Secondly: the public sewers must be completely ventilated; in such a way as to secure a constant current of air through every foot of sewer in the town.

Thirdly: the direct connexion of houses with sewers must, wherever possible, be interrupted; and an efficient independent system of ventilation be applied to every house drain.

Fourthly: means of sewer flushing must be provided, of a nature not to endanger water services. It will be well that they should be such as to allow the whole interior of the sewer pipes to be washed clean, and on occasion to be washed with disinfectant agents.

Fifthly: as regards water services, two things are at once seen to be needful; a separation, as universal and thorough as possible, of all water pipes from sewers and drains in their course along streets and to houses, and disconnexion of all water pipes from the pans of closets. Then, completer information is needed as to the circumstances under which foreign matters can enter water pipes; and this information should be applied in a detailed examination of the course of every water pipe, public and private.

On certain of the matters here adverted to some information will be found in Appendix E. to this report. On points of engineering and law that may be involved in the above recommendations, I make no pretence to speak.

It only remains for me to acknowledge the assistance that I have received from every one with whom this inquiry has brought me into relation; from the Board of Health and its officers, from medical practitioners, and from a vast number of private persons. The help that has been given me has been most spontaneous and cordial. It has been given at the cost of great personal trouble to individuals; and it has been thoughtful and intelligent almost beyond former experience.

P.S.—April, 1876.—As this report is passing through the press, I learn that there has been a very rapid subsidence of fever in Croydon, amounting almost to a disappearance of the epidemic. This fact deserves to be regarded in connexion with the action mentioned in this report as having recently been taken by the sanitary authority. The agent lately employed for the disinfection of sewers has been perchloride of iron.

NOTE A.

Fever in Croydon, 1875.

In Parish of Croydon, and in various Sub-divisions thereof.	Total No. of Houses, 1875.	Houses attacked by Fever, 1875.		Houses having Deaths from Fever, 1875.		Incidence of Fever attacks upon Houses in the several Months of 1875.												Incidence of Fever on Houses.			
																		In the First Six Months.		In the Second Six Months.	
		Number	Per 1,000 of Houses.	Number	Per 1,000 of Houses.	Jan.	Feb.	Mar.		May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Number attacked.	Per 1,000 Houses.	Number attacked.	Per 1,000 Houses.
In total parish, Urban sanitary district.	11,526	959	83	90	7·8	15	53	79	186	* 39	* 30	* 18	* 32	69	275	92	71	402	35	557	48
In parts of parish draining to distinctively Croydon sewers.	10,456	950	91	87	8·3	15	52	79	185	38	30	18	32	69	274	89	69	399	38	551	53
In parts of parish draining to Effra sewers or privately.	1,070	9	8	3	2·8	—	1	—	1	1	—	—	—	—	1	3	2	3	3	6	5
In parts of parish receiving Croydon water supply (note *a*).	9,039	942	104	83	9·1	15	53	78	185	35	30	18	32	68	272	88	68	396	44	546	60
In parts of parish receiving other water supply.	2,187	17	7	7	2·8	—	—	1	1	4	—	—	—	1	3	4	3	6	2½	11	4½
The above combining as follows:—																					
Both drainage and water service on Croydon system.	8,822	939	106	83	9·4	15	52	78	184	35	30	18	32	68	272	87	68	394	44	545	62
Drainage on Croydon system; water not.	1,634	11	7	4	2·4	—	—	1	1	3	—	—	—	1	2	2	1	5	3	6	4
Water on Croydon system; drainage not.	217	3	14	—	—	—	1	—	1	—	—	—	—	—	—	1	—	2	9	1	5
Neither drainage or water on Croydon system.	853	6	7	3	3·5	—	—	—	—	1	—	—	—	—	1	2	2	1	1	5	6

(*a*) Here are included 240 houses within the water area, returned as being supplied from wells, or as having no water at all. As very few of these houses have wells, they are

NOTE B.

Note, containing Analyses of certain Superficial Waters entering Croydon Wells; presented to the Local Government Board February 11th, 1876.

At the present moment so much interest attaches to the water supply of Croydon, both in connexion with recent disease there, and in connexion with a pending application to Government, that I think it desirable at once to communicate to the Board the analyses recently made for the purpose of my own inquiry. For a right understanding of what the waters are that have been analysed, it is needful for me to write a short note on the Croydon wells; and, that the results of the analyses may be properly apprehended, I shall add a few notes upon them. But I shall not anticipate any of the conclusions which it will be my duty to make.

The Croydon Sanitary Authority supplies water from their wells in Sturt's-yard, in the middle of the town, to a large part of their sanitary area. The wells are three, and interest centres at present on the Old Well. The other two, of more recent construction, are believed to be lined to a considerable depth with impervious materials, and to derive their water solely from boreholes, which penetrate into the chalk to the depth of 150 and 130 feet, respectively, below the surface. These wells are not now in question, except in so far as they may, through their connexion with the Old Well, receive any impurity that enters that well.

The Old Well, sunk in 1851, passes through 4 feet of made earth and 11 feet of valley gravel, and enters the chalk at a depth of 15 feet below the surface. The upper 24 feet of its course (that is, all its course through the gravel, and 9 feet more) are of impervious brickwork and cement, seen to be quite dry on the interior when the well is pumped down. Below this, between the depths of 20 and 34 feet where the well is in the chalk, the well is lined with loose brickwork, giving entrance to certain water, which is the subject of the present analyses. At a depth of 34 feet, the borehole of the well begins, and this passes 43 feet further into the chalk, giving the well a total depth of 77 feet. The great bulk of the water of the Old Well comes from the bottom of the borehole; and, while the well is not being pumped from, the water stands in it about 11½ feet below the surface of the ground.

The 10 feet of brickwork, through which water from comparatively superficial sources can enter the well, forms a cylinder of 6 ft. 4 in. in diameter. The water that enters through this brickwork is derived from the upper layers of chalk, and presumably to some extent from the gravel that overlies the chalk. The analyses now presented have been obtained for the purpose of knowing, so far as chemistry can tell, what amount and nature of impurity may be contributed from these superficial sources to the Old Well water, and thus to the Croydon water-supply.

Previous inquiry on this subject has been made by the Local Sanitary Authority itself. On November 29th, at the instance of Dr. Philpot, the Medical Officer of Health, samples of the water entering the open brick-work of the Old Well were collected and analysed by Mr. Wanklyn. They were taken when the water in the soil was probably of average amount, and when "the water was pumped down 32 feet below the surface or about 10 feet below the usual pumping level. The three samples flowed in at about the same level; A from the north side, B from the north-west side, and C from the south side. In no case was the flow of water at these points large in amount; and in the case of B, the flow diminished considerably after a short time."—(Dr. Philpot.)

Mr. Wanklyn's analysis and report are as follows :—

Date—November 29th, 1875.

Name and Description of the Samples of Water.	Grains per Gallon.		Parts per Gallon.	
	Solids.	Chlorine.	Free Ammonia.	Albuminoid Ammonia.
Sample A - - -	27·3	1·4	0·2	·14
Sample B - -	44·0	1·4	·12	·26
Sample C - -	25·0	1·5	·00	·22

Hardness: A, 23°; B, 25°; C, 23°.

A and C are very much charged with sewage, and A is not pure.

Analysis was also made of the *total* water yielded by the Old Well on December 4th, 1875. At this time, water from superficial sources was entering the old well to the extent customary in ordinary seasons and during ordinary pumping; and water was rising through the bore-hole at the usual rate of some million and a half gallons daily. This analysis, like the others, was made by Mr. Wanklyn, at the instance of the sanitary authority, Its results are in figures which have to be read under the same headings as before :—

December 4th.

Sample of water from Old Well, Croydon - - - 24·0 - 1·1 - ·01 - ·04

Water belonging to the most pure class.—Class I.

In collecting samples A B and C it was seen that the side leakage formed but a small proportion to the total yield of the well. The quantity, however, was not measurable, and it was known to be liable to vary, especially with the level of the water in the soil.

The samples which I myself collected and sent to Dr. Dupré, were taken in the middle of the day on January 14th, after the well had been pumped to a very low point on the previous day, and to a point below the top of the bore-hole for some five or six hours. At this date the water in the soil was much more abundant than at the end of November, as was shown by the greater quantity of water flowing along the neighbouring Bourne culvert. A temporary engine was pumping water out of the borehole itself, and the borepipe was exposed in the two feet where it juts up into the well. Hence none of the samples taken from the well were in any degree directly mixed with the deep chalk water; and after the above-described pumping, it is probable that none of them had appreciable admixture with any deep water that might in previous days have flowed out through the brickwork and have returned when the water was lowered in the well.

Sample No. 1 was from a large stream entering at a gap in the brickwork of the well on its north side, at a level 27 ft. 9 in. below the surface of the ground. This stream was stated to be identical with that which furnished sample A for the earlier analysis. Sample No. 2 was taken from a small stream, entering between the bricks near the source of No. 1 on the same level with it. This stream was stated to be in the same neighbourhood as that which gave the November sample B, but could not be said to be in exactly the same place. Sample No. 3 was taken from a moderate-sized stream which issued through a hole on the south side of the well at the same level, and which was stated to have been also the source of sample C taken in November. Sample No. 4 was taken from a very large turbid stream that entered the south side of the well at a level 5 ft. 3 in. below the three before-mentioned streams, at a point scarcely above the jutting top of the borepipe. Sample No. 5 was collected from the basin formed between the well sides and the projecting borepipe. This water was also turbid; it was made up of the aggregate of streams and minor leakages entering the well through the loose brickwork.

Attempts were repeatedly made to measure the quantity of water flowing down the borehole from the bricked parts of the well, but these attempts were

unsuccessful owing to perforation that had been provided in the borehole at the original construction of the well. Such guess as could be made by practised observers put the quantity at 300 to 500 gallons per hour. Of this quantity certainly a half was furnished by streams entering at the lowest level. If 250 gallons an hour entered at higher levels, the three streams from which samples No. 1, No. 2, and No. 3 were taken may be judged to have contributed respectively 120, 25, and 75 gallons per hour. By far the greatest part of the water that entered the upper 6 feet of the loosely-bricked part of the well entered by these three streams.

The five samples were sent to Dr. Dupré without further designation than numbers. He reports on them as follows :—

"Report of Five Samples of Water received from Dr. Buchanan, January 15th, 1876. Each sample contained in one Winchester Quart : stoppers tied over with thin gutta percha : bottles labelled 1 to 5.

"Samples 1, 2, 4, and 5 were, after standing, bright, almost colourless, and remarkably free from organic impurity, as shown by the minute traces of ammonia and of albuminoid ammonia they contain, and the extremely small amount of oxygen they absorb from permanganate. They are of moderate hardness, become very soft on boiling, and have indeed all the characteristics of pure chalk waters. The deposit they yielded (Nos. 1 and 2 in traces, Nos. 4 and 5 in considerable quantities) consisted almost entirely of sand and chalk, with traces only of organic matter, and was, more particularly, absolutely free from living organisms."

"Sample 3 is not so pure. It contains more ammonia and considerably more albuminoid ammonia ; the latter indeed slightly exceeds the proportion a good drinking water should yield. It also contains more chlorine, and absorbs more oxygen than the other four, and, if derived from the same or a similar source has become slightly contaminated by sewage. The deposit consists also of sand and chalk."

"The analytical details are given in the table annexed :—

	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.
Appearance	Clear	Slightly turbid.	Clear	Very turbid	Very turbid
Colour	Almost colourless.	Almost colourless.	Slightly yellowish.	Almost colourless.	Almost colourless.
Taste	Tasteless	Tasteless	Tasteless	Tasteless	Tasteless
Smell	Inodorous	Inodorous	Inodorous	Inodorous	Inodorous
Nitrous acid	None	None	None	None	None
Phosphoric acid	Slight trace	Slight trace	Trace	Minute trace.	Slight trace
Hardness before boiling	15 deg.	16 deg.	15·5 deg.	16 deg.	16·5 deg.
Hardness after boiling	4 deg.	4 deg.	5 deg.	4·5 deg.	3·5 deg.
	Grains per Gallon.				
Oxygen absorbed from permanganate.	0·006	0·010	0·016	0·007	0·007
Total dry residue	24·50	24·36	23·94	23·94	23·20
Consisting of Volatile matters.	1·68	1·68	1·40	1·40	2·38
Consisting of Fixed salts	22·82	22·68	22·54	22·54	21·82
Chlorine	1·26	1·29	1·42	1·26	1·26
Nitric acid ($N_2 O_5$)	1·59	1·74	2·04	1·89	2·12
Ammonia	0·0003	0·0015	0·0028	0·0003	0·0003
Albuminoid ammonia	0·0028	0·0014	0·0077	0·0007	0·0007
Deposit	Trace	A little	Trace	Much	Much
Sand and chalk	—	—	—	43·85	44·76
Volatile matters	—	—	—	0·33	0·31
				44·18	45·07

"Westminster Hospital, Jan. 31, 1876. (Signed) A. Dupré."

App. No. 5.

On Enteric Fever at Croydon, by Dr. Buchanan.

A careful reading of these results, in the light of what has been stated above respecting the sources of the water and the November analysis, gives important information as to the quantity and nature of the impurities received through the loose brick-work of the Old Well.

The stream which enters at the north side of the well, 27 feet below the surface (sample A of November and sample No. 1 of January), underwent material alteration in the six weeks. It had much increased in quantity, and coincidently with this increase had so far improved in quality that the impurities of November were reduced to a "minute trace" in January, and the water had come to be ranked by the chemist with "pure chalk waters." The change appears at first sight to be due to the increased volume of water in the chalk, operating either by diluting the impurity which this stream formerly received, or by diverting some of that impurity from the well; or in both of these ways; but in view of the greater change which an adjacent stream, next to be mentioned, has undergone, it is now probable that the change in sample No. 1 has been in chief part due to the operation of the same drain alteration that has produced the change in that sample.

The small stream (yielding sample No. 2 of January) is also found to be of great chemical purity; although it was taken from about the same place as the most impure sample (B) of November. I believe the improvement here is not so much an affair of dilution, as it has been the result of the substitution (in mid-December) of an iron pipe in place of an earthenware drain with open joints some 25 yards off the well in a north-westerly direction.

On the south side of the well, the stream yielding sample C in November and sample No. 3 in January, which was "very much charged with sewage" at the earlier period, is shown by the later analysis to have remained so charged, though to a less degree. The source of this stream has been lately made out, and it proves to be such that the stream itself, together with much of the impurity it contains, must be regarded as temporary. The stream has come essentially from water discharged from the engine-condenser into a pit just outside the engine house (thence filtering through 20 and more feet of gravel and chalk), and its impurities have come, in part at least, from a leaking drain made of iron, and doubtless designed to keep sewage out of the soil, between this pit and the well. For some years, apparently since the construction of the present condensed water pipe and drain, there has existed an opening in each; that in the water pipe having been filled by a wooden plug which has rotted, that in the drain having been filled by a mass of cement which has ceased to close the orifice of the so-called T-piece which it was intended to close. The occasion of first leakage from water or from the drain pipe cannot be exactly defined, but it is probable that both leakages took their recent proportions only after the commencement of pumping by the temporary engine, operating to put both water pipe and sewer under pressure; that is, after November 22nd. Subsequent plugging afresh of the opening in the water pipe has put an end to the stream from which sample No. 3 was taken.

The stream, yielding the January sample No. 4 on the south side of the well, but at a lower level than the above stream, viz., at about 32 feet below the surface of the ground, is found to be an ordinary chalk water, which was, except for suspended sand and chalk, of a complete purity, so far as purity can be shown by chemical analysis.

As regards sample No. 5, the water of the basin from which this was collected is the aggregate of all the leakages into the well through the open brickwork undiluted with any water from the borehole. Analysis of this water was not made last year, and the significance of the leakages was, even as matter of quantity, left uncertain. The December analysis, indeed, showed that the purity of the total well water was not discoverably affected by the entrance of impurities through the brickwork. It was seen, however, that with dilution to the amount of 60,000 gallons per hour, even worse leakage than that actually observed, might have escaped detection by the chemist, and it was right to regard (provisionally at least) all water that entered the well above the borehole as being of the same foul nature as the samples examined in November. Much interest, therefore, attaches to the analysis of No. 5 sample. In the change of conditions that took place between November 29th and January 14th, the streams entering through the brickwork became, as analysis of them shows, more copious and

ess impure, but it was expected that their aggregate, amounting to not more han 500 gallons an hour, would exhibit a notable quantity of impurity; a uantity that might, indeed, be incapable of recognition after further dilution ith 60,000 gallons an hour of pure water from the borehole, but which would, s it existed in 500 gallons, enable a judgment to be formed of the total impurity eceived through the well sides. Sample No. 5 was collected for the purpose of scertaining the total amount of this impurity, and the lesson learnt from it is o this effect:—That the impurities contained in particular leakages, including hat from which sample No. 3 was taken, are lost so as to be unrecognisable by he chemist, in the aggregate of leakages, amounting at the outside to 500 allons per hour. This aggregate is pronounced by Dr. Dupré to have "all he characteristics of pure chalk waters," "with traces only of organic matter," nd to be "more particularly, absolutely free from living organisms."

Looking at this result; looking also at the improvement that has taken place n the streams from which samples No. 1 and 2 were taken; and again, looking t the nature of the conditions that have been recently befouling sample No. 3, he conclusion is forced on me that the sources of impurity to the Old Well are lefinite and removable, consisting of a few nuisances in the immediate neigh- ourhood of the well.

Until I make my report upon the whole case at Croydon, I do not pretend to peak finally on the part which this well may have played in the fever epidemic here; but as regards the present and the future, the sources of pollution which I ave found existing are such as to admit of being entirely removed, and it is for he purpose of saying this that I have thought it desirable to write this provi- ional memorandum. I think it right to add, however, that, recognizing as I lo the necessity for every precaution to ensure safety to wells situated in the niddle of the town, I cordially approve the action which the sanitary authority s taking in lining the Old Well with iron cylinders down to the level of the bore- ole, for keeping out of the well all water except that derived from the deeper arts of the chalk.

(Signed) George Buchanan.

February 11th, 1876.

NOTE C.

The following Analyses have been made by Dr. Dupré of Samples of Water taken from Croydon Mains and House Services; the samples as ent to him were distinguished by numbers only:—

Sample A was taken (see p. 50) from the "arterial main" in Park Lane at 4.20 a.m. on February 12, 1876.

Sample B was taken from the main pipe at the junction of the Cargreen and Lawrence Roads at 5½ o'clock on the same morning.

Samples C and D were taken from a house in the Cargreen Road, where the house-service pipe was leaking somewhat. C was from the main-tap, D was from the house cistern. They were taken immediately after sample B.

Samples E and F were taken from a house at the corner of Cargreen and Lawrence Roads, where (p. 51) the water had been sometimes observed to have a smell "like onions." E was from the main-tap, F was from the house cistern. They were taken immediately after samples C and D about 6 a.m. on the same morning.

Sample G was taken from a main-tap in a house in the Birchanger Road at 5 p.m. on February 13th, under circumstances referred to in the Report, page 52. This sample did not reach Dr. Dupré till February 16th.

Dr. Dupré observes upon the several samples as follows:—

"Each sample contained in two Winchester quarts, stoppers tied over with string, and in addition with oilsilk in sample A, with guttapercha in samples B–E, and with paper pasted over in sample G.

"All the waters are colourless, tasteless, and inodorous, and are in every respect pure and excellent. They are all practically identical, such differences as were found being in almost every case within the limits of experimental error. The most appreciable difference is shown in the deposits."

The analytical details are given in the table annexed :—

	A.	B.	C.	D.	E.	F.	G.
Appearance	Clean	Slightly turbid	Slightly turbid	Clear	Veryslightly turbid	Clear	Clear
Colour	Colourless	Colourless	Colourless	Colourless	Colourless	Colourless	Colourless
Taste	Tasteless	Tasteless	Tasteless	Tasteless	Tasteless	Tasteless	Tasteless
Smell	Inodorous	Inodorous	Inodorous	Inodorous	Inodorous	Inodorous	Inodorous
Deposit	Very minute trace	A little	Very little	Minute trace	Very little	Very minute trace	Very minute trace
Nitrous acid	None	None	None	None	None	None	None
Phosphoric acid	Trace	Trace	Trace	Slight Trace	Slight trace	Slight trace	Slight trace
Metallic impurities	None	None	None	None	None	None	None
Hardness before boiling	16·3	16	16	16	16·5	16·2	16·5
„ after „	2·8	3	3	3	2·5	2·8	3·
				Grains per Gallon.			
Oxygen absorbed from permanganate.	0·004	0·003	0·004	0·004	0·003	0·004	0·005
Total dry residue	21·70	22·54	21·98	22·54	21·84	22·12	22·12
consisting of volatile matters.	1·54	2·24	2·10	1·76	2·24	1·82	2·03
consisting of fixed salts	20·16	20·30	19·88	20·78	19·60	20·30	20·09
Chlorine	1·01	1·01	1·01	1·01	1·01	1·01	1·01
Nitric acid ($N_2 O_5$)	1·36	1·36	1·36	1·43	1·36	1·29	1·36
Ammonia	0·0007	0·0014	0·0007	0·0005	0·0003	0·0007	0·0014
Albuminoid ammonia	0·0414**	0·0035	0·0014**	0·0028	0·0028	0·0030	0·0033
				Cubic inches.			
100 cubic inches of water contains—							
Uncombined carbonic acid.	0·56	0·45	0·63	0·88	1·00	0·52	0·63
Oxygen	0·83	0·98	0·88	1·10*	0·83	0·72	0·90
Nitrogen	1·78	1·96	1·66	2·50*	1·62	1·68	1·78
Sulphuretted hydrogen.	None	None	None	None	None	None	None

* Evidently somewhat over-estimated. ** These two form perhaps the only exceptions to the otherwise general agreement; the albuminoid ammonia is certainly below the others.

A. Dupré,
Westminster Hospital.

NOTE D.

[*From Memoirs of the Geological Survey, Vol. IV., Part I., pp.* 543–4.]

Croydon.—Well for the Local Board of Health [Old Well]. Sunk and communicated by Messrs. T. Docwra & Son (some particulars added from a MS. section in the Engineer's Office, Metropolitan Board of Works). Yields 1,500,000 gallons a day.

		Feet.
Made ground		4
[Valley drift, 11 feet.]	Rough loamy gravel	4
	Sand	½
	Finer loamy gravel	3½
	Coarse gravel	3
Chalk, 62 feet.	Hard chalk with large flints	15
	Chalk	24
	Hard crust (the greatest supply of water comes from this)	1½
	Chalk	21½
	Total	77

Croydon.—New well for the Local Board of Health, 1864, 56 feet from the older well. Sunk and communicated by T. Docwra & Son. Water rose to a height of 11½ feet below the surface.

		Feet.
Made Ground		5¼
Gravel, 9¾ feet.	Black gravel	1½
	Grey gravel	1
	Red gravel	¼
	Yellow gravel	7
Chalk, 137 feet.	Chalk (with rough gravel 7 ft. down on one side of the well)	23
	Chalk (layers of flint every 6 inches)	10
	Flints and chalk	16
	Flints and rock chalk	29
	Hard chalk	11½
	Yellow chalk	2
	Rock chalk	4
	Chalk and flints	13
	Blue clay	½
	Chalk and flints	12
	Grey chalk	1
	Chalk and scattered flints	8
	Soft chalk	7
	Total	152

App. No. 5.

On Enteric Fever at Croydon, by Dr. Buchanan.

CROYDON PARISH: FEVER AND RAINFALL.—Twenty-five years since the construction of the Bourne culvert and the sinking of the Old Well; showing for each year the deaths from fever; the fever death-rate per 10,000 of population calculated from census data; and the rainfall: with facts as to the flow of the Bourne. (From Dr. Westall's tables, continued by Dr. Philpot: the rates calculated by myself.)

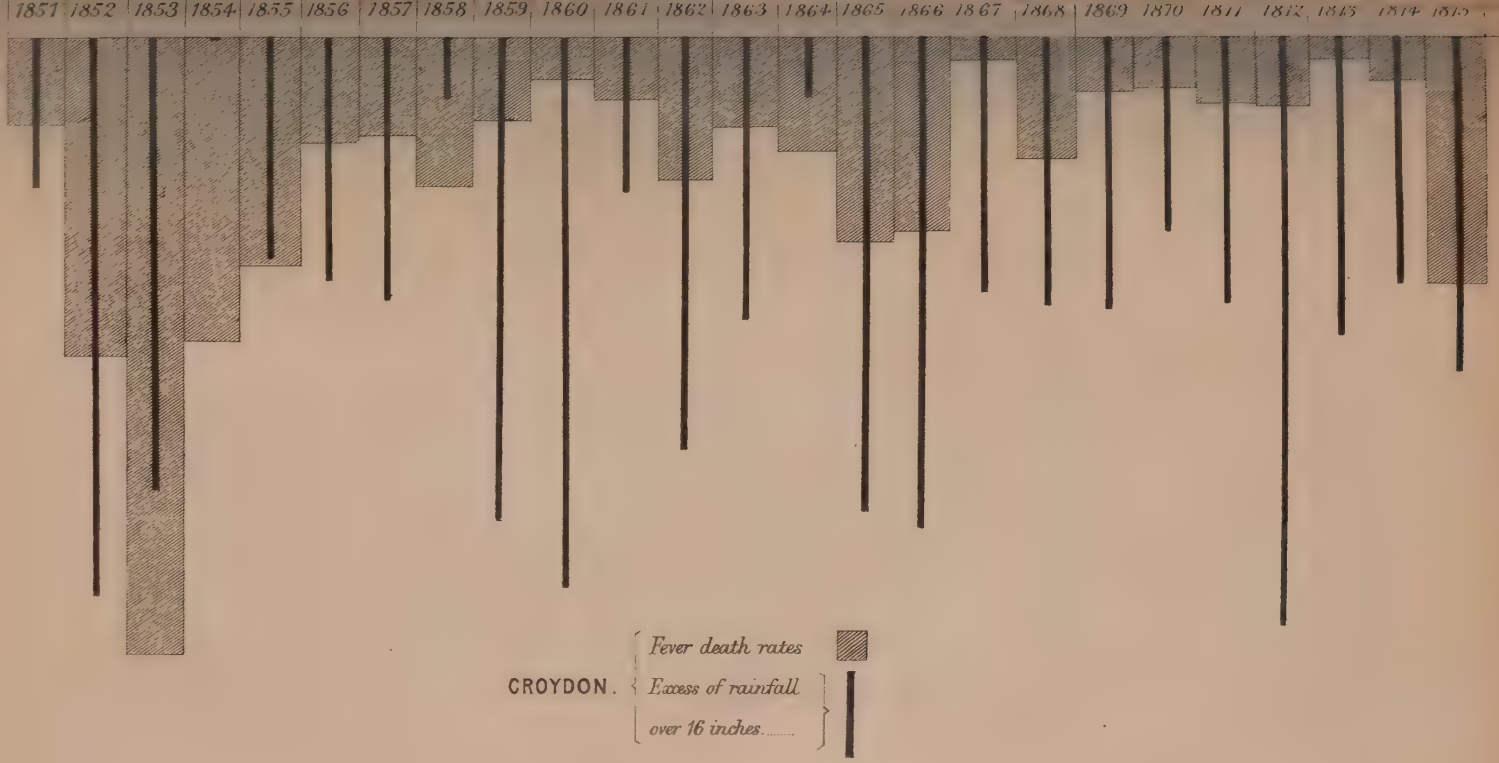
Year.	Fever Deaths.	Rate.	Inches of Rain.	Flow of Bourne.
1851	10	·49	21·01	
1852	38	1·81	33·92	Moderate.
1853	76	3·52	30·51	Copious.
1854	39	1·75	16·02	
1855	30	1·30	23·26	
1856	14	·59	23·95	
1857	14	·57	24·88	
1858	22	·86	18·09	
1859	10	·37	31·82	
1860	7	·24	33·82	Moderate.
1861	11	·36	21·00	
1862	27	·82	29·42	
1863	19	·52	25·01	Small.
1864	27	·66	18·02	
1865	52	1·19	31·47	
1866	51	1·11	32·38	Moderate.
1867	7	·14	24·16	
1868	36	·71	24·58	
1869	19	·35	25·04	
1870	18	·32	22·27	
1871	22	·38	24·54	
1872	24	·41	35·27	Rather copious.
1873	9	·15	25·71	
1874	17	·27	24·10	
1875	90	1·42	26·87	

The relations of the above are shown in the annexed diagram, the yearly fever-rate being shown by a length of shading; and the excess over 16 inches of the year's rainfall being shown by a length of black line.

[The Croydon rainfall is commonly something larger than the Greenwich rainfall. The excess was formerly seldom more than 2 inches, but in recent years (perhaps owing to a change of observation station at Croydon) the excess has sometimes reached 4 inches. No notice of this fact is taken above or in the diagram.]

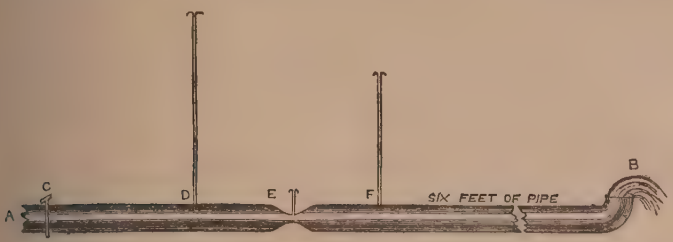
NOTE E.

I. The fact that currents from without inwards occur through apertures made in the sides of pipes running full of water is well known, but I have not been able to find an account of the conditions under which these currents are produced. Making some experiments at the Waterworks yard, with the assistance of Mr. Walker, the engineer of the Board, I find (1) the lateral incurrent is freely produced when the water pipe is descending and when the pipe beyond the hole is unobstructed; (2) if the force of waterflow in a descending pipe be moderate, a moderate degree of obstruction beyond the hole does not prevent the incurrent; (3) in horizontal pipes of uniform calibre, when the flow is strong or the pipe beyond the hole is long, or when the end of the pipe is at all turned upwards, the incurrent does not take place, but (4) momentary interference with flow, *a tergo*, or momentary reduction of obstruction, *a fronte*, allows of a momentary incurrent through the hole; (5) incurrent through a lateral hole takes place with incomparably greater ease when the hole is made at a point of constriction of the water pipe.



Fred^k Dangerfield. Lith

The following is an experiment illustrating the conditions under which these ateral incurrents may be produced in horizontal pipes. The constriction of he pipe, in this and other experiments, was suggested to me by the address of the President of the Mechanical Section of the British Association, W. Froude, Esq., C.E., F.R.S., published in "Nature," in November 1875.



A pipe A B was arranged as shown in the above diagram, the end near B being of indiarubber so that B could be readily closed, and a piece of glass tube being inserted where the break is shown. The end A was attached to a water main running under some hundred feet of head. The pipe had a constriction in it at the point E. Three openings were made on the upper side of the pipe, one at the point of constriction, one D behind, and one F before that point. The tap C being turned on, no matter whether wholly or partially, while B was closed, the indiarubber tube was distended almost to the point of bursting, while long jets issued from the apertures at D E and F. The tap C being turned fully on while B was open, shorter jets issued from the side apertures, their relative heights being somewhat as shown in the diagram. By partial closure of the tap C, these jets were diminished in height, as if by the subtraction of a constant quantity, and the flow from E would be reduced almost to zero, while D and F were sending out jets of a foot or two in height. If, while this is going on, the tube at B were compressed, all three jets at once rose, and the indiarubber pipe swelled as usual; but upon removing the obstruction at B, the effect was for the moment to reduce all the jets below the height to which they had originally risen; the flow from D and F was diminished by some inches, and air entered at E and was seen to pass along the glass pipe. In the next moment the original levels were regained, and air ceased to enter at E. The circumstances that facilitate entry of air through a side hole in a horizontal pipe act *a fortiori* in a descending one.

It seems to me that conditions for the production of lateral incurrents into water pipes may very largely exist at Croydon, perhaps on some larger services, but pretty certainly on many house services. A water pipe descending from the main to a house-basement, to a sink, to a servant's closet, or to a "draw-off" tap, would have the best opportunities for insuction of matters through any hole in its course. But from the above experiment it does not appear that any actual descent is necessary; and it would seem that a leaky sluice-cock on a house water-service pipe furnishes conditions resembling the constriction and perforation (E) of the experiment.

I write the above with much diffidence, as this branch of physics is one with which I am not familiar; but enough, I think, appears to justify the advice that more information on the whole subject should be got. About the importance of indraught into water-service pipes there can be no question, and the very possibility of it, under any circumstances, furnishes an ample reason for dissociating everywhere in their course all water pipes from sewers and drains.

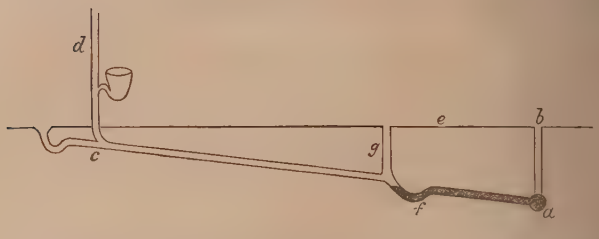
In Croydon, out of a total of 1,291 leaky pipes, taps, and valves of all sorts detected in 1875, there were found 73 leaky service pipes to houses, some of them close to drains or sewers.

It will be observed that experiences considered under the present head must have special concern for districts that are on a "constant service" system.

II. For the purpose of making the separation, advocated in the text, between the air of public sewers and of house-drains, an arrangement of the sort figured in the subjoined Diagram II., may properly be substituted for the existing arrangement which is shown in Diagram I.

(I.)

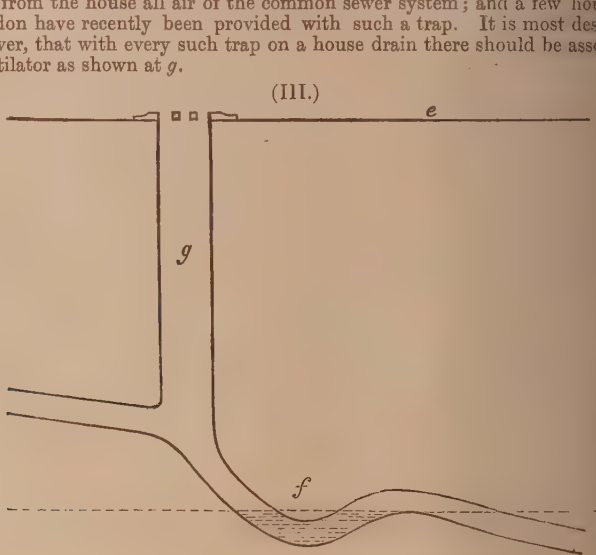
(II.)



a. Public sewer.
b. Ventilating shaft of the public sewer, habitually more or less blocked by charcoal trays. These shafts need to be multiplied. The charcoal trays have already been removed.
ac. House drain.
d. Ventilating pipe of house drain, now habitually too small and requiring to be of the full calibre of the soil pipe.
e. Edge of house precincts.
f. Trap, and *g* ventilator; shown of larger size in Diagram III.

Under proper conditions of the public sewers, the trapping bend (*f*) will keep away from the house all air of the common sewer system; and a few houses in Croydon have recently been provided with such a trap. It is most desirable, however, that with every such trap on a house drain there should be associated a ventilator as shown at *g*.

(III.)



Such a ventilating opening serves three purposes, (1) if the trap (*f*) be ever forced by pressure of air in the public sewer, an immediate exit of the sewer air away from the house is afforded; (2) a continuous ample ventilation of the house drains is provided,—without such opening the prolonged soil pipe merely affords relief to concentrated and urgent drain-air; and (3) a means for inspection of the trap (*f*) is provided, and a way to clean it out if ever it should become choked. It may be observed in diagram III. the drain from the house to the trap is represented as on a higher level than the drain from the trap to the sewer, a longish piece of sharp slope just before the trap being thus obtained. With this contrivance, and in duly proportioned drains, stoppage in the trap is not to be greatly apprehended; and, as before said, if it should occur, it can at once be detected and removed.

The arrangement here shown isolates each set of house drains into a wholly distinct system as shown by the double lines in Diagram II. Even if there should be a little smell from the opening (*g*) it can only be derived from matters that have passed into the drain from the house, and cannot have any fever infection with it, unless there be fever in the house itself. But in effect (I speak from experience of the arrangement under its most difficult conditions) there is seldom any smell whatever from this opening (*g*), for when the drains are in good order it habitually acts as an inlet for air that goes up the ventilating pipe (*d*) by the side of the house; if the drains are not in good order, there may be smell from this lower opening, and such smell should be welcomed as an indication (otherwise wanting till ill-health occurs) of something about the drains requiring amendment.

I, of course, leave constructive details to others, not professing to define the mechanical arrangements by which the principles here set forth may be fulfilled.

It ought to be no objection to this arrangement that the house-drain ventilators (*d*) can no longer serve for the ventilation of public sewers. It is not the business of householders to ventilate public sewers; that is the affair of the authority in whom those sewers are vested. In Croydon the direct connexion between public sewers and the pipes that run up the sides of houses is not only dangerous to the houses, but, in relation to public sewer ventilation, the arrangement is little more than a sham.

III. The following regulations, indicating the right method of supplying water to waterclosets in a place where the so-called "constant service" plan of water delivery is in use, are extracted from the "Regulations under the Metropolis Water Act, 1871." These regulations, having for their object the "preventing of undue consumption or contamination of water," are the result of an inquiry made for the Board of Trade by Lord Methuen, Captain Tyler, and Mr. Rawlinson, C.B. They have the sanction of the Board of Trade and may be put in force by the London Water Companies:—

"20. Every boiler, urinal, and watercloset, in which water supplied by the Company is used (other than waterclosets in which hand flushing is employed), shall, within three months after these regulations come into operation, be served only through a cistern or service-box and without a stool-cock, and there shall be no direct communication from the pipes of the company to any boiler, urinal, or watercloset."

"24. No pipe by which water is supplied by the company to any watercloset shall communicate with any part of such watercloset, or with any apparatus connected therewith except the service-cistern thereof."

No. 6.

App. No. 6.

On Scarlatina at South Kensington, by Dr. Buchanan.

Dr. Buchanan's Report on an Outbreak of Scarlatina in South Kensington.

The following history is of scarlatina attacking a number of people apparently not directly exposed to the infection of an antecedent case.

At a house in South Kensington the household consists of a gentleman and his wife, two sons, four daughters, and two young children; a butler and footman; a cook, kitchenmaid, upper and under housemaid, nurse, and lady's maid. The younger son is absent at the time in question. On June 8th, 1875, the two young children with their nurse leave home and go to the seaside.

On June 9th, 1875, a dinner party is given at this house, 12 guests sitting down to dinner with the host and hostess, their eldest son and daughter. In the evening these 16 persons, together with the other son and daughters and some 150 other guests, assemble in the drawing rooms. On this day the service of the house is reinforced by an extra cook, five waiters, and a charwoman.

In this Report, using letters for names, I shall designate the host's family by the letter A., and the several members of it as follows: A_1, the host; A_2, the hostess; A_3 and A_4, their eldest and second sons; A_5, their eldest daughter; and A_6, A_7, and A_8, their other three daughters. The letters B., C., to K. will stand for such guests as have to be individually indicated; two guests of one family being shown by 1 and 2 following the same letter.

Between June 11th and June 14th the following fall ill:

Of the family, four out of seven who were in the house on June 9th. — Scarlatina, first attacks.

- (1.) A_2, the hostess;
- (2.) A_5, the eldest daughter;
- (3.) A_6, the second daughter;
- (4.) A_7, the third daughter;

Of the servants, three out of seven who were in the house on June 9th.

- (5.) Cook; probably scarlatina, had scarlatina formerly.
- (6.) Lady's maid; scarlatina, first attack.
- (7.) Kitchenmaid; sore throat, had scarlatina when a child.

Of the dinner guests, six out of twelve.

- (8.) B., lady; slight scarlatina, had scarlatina formerly.
- (9.) C., lady; doubtful scarlatina, never had scarlatina before.
- (10.) D., lady; sore throat, never scarlatina before.
- (11.) E_1, gentleman; scarlatina, first attack.
- (12.) E_2, lady; scarlatina, first attack.
- (13.) F., lady; sore throat, had scarlatina formerly.

Of the evening guests, these only (so far as known) out of some 150.	(14.) G., lady; slight scarlatina, had scarlatina formerly.
	(15.) H., lady; sharp scarlatina, first attack.
	(16.) I., lady; scarlatina, first attack.
	(17.) J., gentleman; sore throat, œdema of glottis, never scarlatina before.
Of the occasional servants.	(18.) Charwoman; sore throat, never scarlatina before.

Hence within five days of June 9th, 12 persons who were in the house on that day are attacked with scarlatina, and six others with sore throat, or with sore throat and other symptoms resembling scarlatina. Besides these there was a 19th attack in the person of K., a lady who was not in the house on June 9th, but who lunched there on the 10th and was taken ill with slight scarlatina (second attack) on the 14th. Moreover, one of the waiters had an equivocal attack (does not know as to previous scarlatina), but not till June 18th. One of the evening guests had, within a few days of the party, a sore throat which her medical adviser believes was not scarlatinal; and another guest (a gentleman) at the evening party is reported to have suffered in a similar way to J., but of this guest no particulars have been ascertained.

These were all the cases that could be heard of up to the middle of July. The two children who went to the seaside on June 8th remained with their nurse perfectly well.

The cases here definitely mentioned as "scarlatina" were seen by medical practitioners (seven in number), and no case is here put down as scarlatina except upon medical diagnosis. Of the six cases recorded as "sore throat" and "doubtful," two did not come under medical care at all, in three the symptoms were not such as to allow the medical attendant to affirm the nature of the illness, and in the sixth (J.) no question of scarlatina presented itself to the medical attendants. When the coincidence in point of time and circumstances, between these six cases and the 13 positive cases is taken into account, a presumption arises that some at least of the five may also have been scarlatinal in their nature. All the patients recovered, J. not without the operation of tracheotomy. Kidney affection is not known to have occurred in any of the cases, and is known not to have occurred in most of them.

The following are the details of one of the cases probably about or below the average in severity. The notes are furnished to me by the Resident Medical Officer of the London Fever Hospital:

Laura —, aged 26, admitted June 14th, 1875. Patient is lady's maid in a family living in ——, South Kensington,. As far as she knows she has not been exposed to any infection. She has never had a previous attack of scarlatina. Three days ago she was taken ill with sore throat; she had no vomiting and no rigors. No redness of her skin was observed until the day of her admission into the hospital. On admission, she had a slight scarlatina rash on chest and hands, tongue furred in middle, edges red. Fauces injected, and tonsils swollen; no white patches on tonsils. Evening temperature (E.T.) 101·2°. June 15. Morning temperature (M.T.) 101·0°. No alteration in symptoms. E.T. 101·4°. June 16th, morning T. 101·9°. Less rash; tongue still coated with white fur. Bowels open. Fauces less red; has less pain on

swallowing. E.T. 101·2°. June 17th, M.T. 99·2°. Rash fading. E.T. 100°. June 18th, M.T. 98·0°. Tongue cleaning; rash nearly faded. E.T. 100·2°. June 19th, M.T. 98·8°, E.T. 100°. Rash faded. June 20th, M.T. 98·2°, E.T. 100·2°. June 21st, M.T. 99·2°, E.T. 99°. Tongue clean. June 24. Going on well; no desquamation. June 29th. No albumen in urine; cuticle comes off hands in washing. June 30th. No albumen; fingers desquamating slightly. July 1. No albumen; fingers desquamating still but little. July 2. To get up. July 3. No albumen; no desquamation anywhere but on hands. July 6. Hands still slightly desquamating.

In the management of the outbreak, precautions of the nature of isolation and disinfection were very generally observed,—as generally and as thoroughly as was to be expected. Beyond those originally attacked the disease did not spread, except in the form of feverish sore throat to persons in communication with two of the patients.

At this point, as the remainder of this report will be devoted to questions of etiology, I put together some considerations of interest bearing on the natural history of the disease. First, I recall the absence of any death out of 19 attacks, and the immunity of the patients from kidney disease. Secondly, I note that four persons who had not to their knowledge had scarlatina before and who were exposed to circumstances apparently identical with those that produced scarlatina in 13 others, had no scarlatina rash, but some form of sore throat: one of these four having serious laryngeal symptoms. Thirdly, I note the singular absence of contagion, even from the well-marked cases, to other susceptible persons. That this was not wholly due to the precautions that were taken appears probable from several considerations: for example, there was no spread of scarlatina from case A_7 to A_8, though the girls slept together for two nights after A_7 had become ill.

I became cognizant of the earlier facts of this history on June 17th, and at once set to work to note the progress of the outbreak, and to investigate, as far as I could, its causation. From the medical officer of health of the district, and from the registers of death, I learnt that there was but little scarlatina in the South Kensington neighbourhood, no amount which, if it were multiplied by a hundred, would allow the outbreak to be regarded as being simply a part of a current diffusion of the disease. It was soon apparent too that, except for the meeting at this particular house, there was no common centre of infection or other common local circumstance to account in any degree for the disease attacking these particular persons. I had therefore to confine my attention to the conditions to which the particular household and guests were exposed, and at once saw that the condition causative of disease must have been limited to the particular day, June 9th, or to that day and one or two days near it. That such condition was not operative before June 9th was seen to be probable from the fact that two susceptible children who left the house on June 8th escaped the disease altogether, and these are good reasons for believing that the condition cannot have remained operative for longer than one day or so after June 9th.

Of conditions able to produce scarlatina, and acting under these limitations of place and time, the first that demanded inquiry was any possible personal infectiousness of the household or occasional servants. Now it is certain that for some indefinitely long time before June 9th there had been no scarlatina nor anything resembling it in the household, and careful inquiry failed to discover that any of the occasional servants had recently had scarlatina in their persons or in their families. There was no reason to believe that any member of the household or occasional servant had recently been in communication with any case of

scarlatina. Obviously evidence on this point could not be positive; but even supposing some communication of this sort had actually taken place, it might account for attacks among individuals so exposed, or possibly for some stray further case, but it could not possibly account for the series of events above described. The circumstances of the outbreak are not such as to suggest infectiveness from guests, but it was ascertained that of the dinner guests none had scarlatina in their households.

At a late period of the inquiry, a notion was for the first time heard of as being entertained by the cook, that the extra cook engaged on the day of the dinner had her hands peeling at the time. I saw this extra cook in the last week of June, and she then had no desquamation, and told me with apparent truthfulness that she had been perfectly well and that nobody in her house had been ill with any complaint.

The evidence respecting direct infection being thus negative, the inquiry was pushed into various other directions. As for fomites, the only sort that circumstances at all brought under suspicion was the dress of some lady member of the family; but, besides that infection of a dress would not explain the observed incidence upon kitchen servants, it was learnt that of the host's family none of the ladies had new dresses on June 9th, but had before worn the same dresses without ill results to themselves or others. As for local conditions in the house of a kind to generate or convey disease-contagion, they were carefully sought for, but, beyond a full dust bin, no condition of the sort could be discovered, and the dust bin contained nothing beyond the legitimate and everyday contents of such receptacles. Thirdly, the adjacent mews was searched for scarlatina in the people and for any disease among the animals there. This, again, was without result, the only disease discovered being that in the stable next to that behind the house a horse was suffering from "strangles," with old tracheal symptoms, and discharge from the nares. But there was no scarlatina in the mews.

From the first the fact of a dinner party being especially attacked by scarlatina and sore throat had been seen to have a possible significance as bringing in question articles of food or drink. But inquiry in this direction was not elaborated until other more usual causes of the disease were proved to be absent.

The circumstances of the outbreak were now passed under review from this new aspect, and there was soon seen to be some strong *a priori* evidence in favour of the disease having been distributed by means of food.—A number of articles of food not in everyday use were consumed on the particular day, June 9th. The guests at the dinner table, who were the persons who most consumed these articles, suffered most under the subsequent attacks. Servants employed in the preparation of food were attacked more than other servants. The children and nurse, who could not have taken any article of food supplied on the 9th, escaped. A lady who was not in the house on the evening of the 9th, but who lunched there on the 10th, was attacked. The host's family itself suffered to an exceptional degree. On inquiry it appeared that every member of this family who was attacked had double opportunities of partaking of articles supplied to the house on the 9th, while of the members of it who escaped the two were at dinner (A_1, and A_3) had just the same opportunities as the dinner guests. The facts as to the three younger daughters are striking. None of them were at the dinner. All were at the "at home." One of them, going to a picnic next day, went to bed early without taking any evening refreshment, and was not

at lunch on the 10th: she escaped scarlatina altogether. The other two were helped from the supper table and from the lunch table next day; and they both fell ill with scarlatina on the 13th and 14th respectively.

In short, it only needs two easy suppositions to bring all the facts (thus far learnt) of the case into harmony with the view that the scarlatina contagium was distributed by means of some article of food or drink supplied to the house on June 9th. These suppositions are that the article in question was more consumed by ladies than by gentlemen, and that it was much more consumed by the dinner guests than by the evening guests.

The above circumstantial evidence in favour of the outbreak of scarlatina having been by food or drink, and the evidence against its having been due to any other cause must be allowed considerable weight; and I am desirous of pointing out in this place that the evidence so far is independent of any identification of the particular article of food, and is independent of any demonstration of how any article of food can have received its infecting quality. One article of food will presently come into special question, and the story of its relation to persons having scarlatina will be told. This story may or may not add to the foregoing probabilities respecting the source of disease, but nothing that follows can weaken the chain of evidence by which it is above shown to be probable that scarlatina was here introduced by means of something eaten or drunk.

It was manifestly impossible for one person having other engagements to investigate the circumstances of origin and distribution of every article of food that was on the several tables on June 9th. Limitation of the inquiry being essential, it was made in view of the consideration that the article would probably be found among those which had to some extent served the evening party as well as the dinner party. Of these articles, one, and one only, was soon discovered to present some promising speciality of origin and distribution, and it was to this article that the time able to be given to this part of the inquiry was thenceforward restricted.

This was the milk and cream supply, which was regarded as particularly deserving of investigation for other reasons than the foregoing. It had been seen that, in the absence of any strong personal infection, the singularly large proportion of the household and dinner guests attacked, and the similar circumscription of the outbreak both in place and time, presented a strong similarity to the phenomena presented in certain, now numerously recorded, outbreaks of enteric fever, where the material of the disease had been distributed through water or milk. Water was not here in question, so that milk seemed to be particularly worth investigation in its relations to an outbreak, though of another disease, where something eaten or drunk was presumably concerned. But further, there are on record two, if not more, instances of scarlatina itself being diffused by milk, with resulting outbreaks similar to the present, both in the proportion of people affected and in the simultaneouness of attack.

These outbreaks were at St. Andrews in 1869, and at Leeds in 1872. The former of these was well investigated and recorded by the late Professor Oswald Bell, of St. Andrews. Here 26 people were in a short period attacked by the disease. "On making out a list on the spot of houses in which scarlatina had "shown itself in St. Andrews, and on asking the farmer's wife for a list of the "houses which she supplied in the town with milk, the lists, with one excep- "tion on each side, were the same. The exception on the side of the milk "supply had reference to a house where two elderly ladies lived with no young

'people near; that on the side of the scarlet fever referred to a mild case of a 'child in a large family, none of whom took the fever." The farmer's wife had milked her cows while nursing a child with scarlatina. The milk boy, having first sore throat, and afterwards desquamation of cuticle on hands and feet, carried milk to town all the while. In both ways, Professor Bell inferred, the contagion was conveyed with the milk from the farm to the town.

The history of the other outbreak was generally similar.

Now at this house in South Kensington, besides an extra supply of milk from the ordinary source, a store of cream was taken in on the particular day, June 9th. And this cream was delivered, partly at 4 o'clock, partly at 5 o'clock in the afternoon. On inquiry of the milkman, Mr. N., respecting the source of the cream, the interesting fact came to light that it was not the same in the two supplies; for that sent in at 4 o'clock had come exceptionally from a London dairy kept by Mr. M., while that sent in at 5 o'clock was taken in the way usual in Mr. N.'s business from milk that had travelled up from Hampshire.

Mr. N. is not sure whether the 5 o'clock supply may not have contained some cream furnished by Mr. M.'s cows. The man who delivered that supply believes it did. But the 4 o'clock supply was "double cream," and was fetched by Mr. N. himself from Mr. M.'s dairy.

Now the cook explains that the 4 o'clock supply was used essentially in the preparation of dishes of ice pudding, custard, and "creams," whereas the 5 o'clock supply was sent up to the dinner and evening tables for eating with fruit and for use in coffee and tea. Of the 4 o'clock cream, however, some that was in excess of cook's requirements was put into one or two jugs along with more or less of the 5 o'clock cream. Hence while the general cream supply of the day was from a Hampshire dairy, the distinctively dinner supply was from Mr. M.'s London dairy.

Evidently, so far as there may be question of milk in relation to the scarlatina, the question can hardly, if at all, concern the 5 o'clock (Hampshire) supply, which was partaken of by large numbers of evening guests without any result, but the question must be of the 4 o'clock supply, that which came from Mr. M.'s dairy, that which was used on the one hand in preparation of dinner dishes, and on the other hand to some very limited extent in the same way as the other supply. For the 4 o'clock cream was distributed essentially to the family and to the dinner guests; and next day, in the shape of certain dishes that had come untouched from the dinner table, to four ladies of the family and their then guest. And scarlatina was distributed essentially among the family and to the dinner guests, with special incidence on the ladies who were at lunch next day. On the other hand, the 4 o'clock cream was not generally distributed to the evening table, and scarlatina, too, was not generally distributed among the evening guests. It is thus seen that the 4 o'clock cream and the scarlatina went, in the main, together, though there were exceptions which obviously required, and promised to reward, more particular study.

It has been attempted to push on the inquiry to the point of learning which individuals of the family and of the dinner party took cream, and in what form they took it. For 19 of the 20 persons of these classes the facts have been learnt with a considerable degree of exactness, and they are recorded in the following table. For one guest who escaped, and who had had scarlatina some four years ago, the facts have not been ascertained. Something has also been learnt respecting certain evening guests.

Inquiries into form in which (if at all) Cream was taken by various Persons.

Persons and form of cream taken.	Persons afterwards ill.	Persons who remained well.
Inquiry made of eleven guests at dinner, numbering	6 persons.	5 persons.
By 8 of the 11, cream was taken in some form or other, viz.:—	by 6.	by 2.
At dinner, in ice pudding	by E_1.	by 2 guests.
At dessert, with fruit	by C.	by no one.
In dining room, with coffee	by E_1.	by same 2 guests.
In drawing room with coffee	by B., C., D., E_2., and F.	by no one.
At evening table	by no one.	by no one.
Inquiry made of eight members of the A family, including their guest of the 10th, numbering	5 persons.	3 persons.
By 6 of the 9, cream was taken in some form or other, viz.:—	by 5	by 1.
At dinner in ice pudding	by A_2. and A_5.	by no one.
At dessert, with fruit	by A_5.	by no one.
In dining room, with coffee	by no one.	by A_1.
In drawing room, with coffee	by A_2. and A_5.	by no one.
At lunch on June 10, in "cream"	by A_2., A_5., A_6., A_7., and J.	by no one.
Inquiry made of four evening guests and their immediate companions, numbering	4 persons.	8 persons.
By 4 of these cream was taken with fruit, or in tea or coffee	by 4	*See note.*

Five companions of three of these evening guests had no cream. Three companions of the fourth evening guest are doubtful whether or not they took any.

It will be observed that of those of the family and dinner guests who were afterwards taken ill all had partaken of cream in one form or other, while of those who were not taken ill a majority had not used cream in any form; further, that the incidence of attack was parallel to the use of cream in certain particular forms. Thus, while the ice-puddings were eaten equally by those who were attacked and those who esacped, no less than seven ladies who were at the dinner, and took cream with their coffee in the drawing room, became afterwards ill, none of them who took that cream having escaped. There was not the same incidence on the gentlemen who took cream with their coffee in the dining room. So of next day's "cream" in its relation to the family and their guest, all those who partook of it were afterwards ill; of those who did not partake of it, no one person was ill.

After what has been said of the distribution of the 4-o'clock cream, something of the above sort is exactly what would be expected on the hypothesis of that cream having been at fault.—The portion of that

cream put uncooked (as before mentioned) into one or two jugs, filled up and refilled from a store of harmless cream, would be expected to work its effects on a small number of persons only; and if it were sent to a defined group of individuals, to cause them to be affected in a group, while others remained free. What if one particular jugfull among many on the evening table contained some of this 4 o'clock cream? Again, cook thinks that one jug, which she remembers to have filled or partly filled from the 4 o'clock supply, was sent to the dining room for gentlemen's coffee. What if, instead, that particular jug was sent into the drawing room for ladies' coffee? Once more, the bulk of the 4 o'clock cream was used for dishes in the preparation of which cream is stirred into other ingredients while they are cooling after having been boiled, or of dishes frozen before being sent to table—custards, "creams," ice puddings. I am not able to guess what may have been the influence of these processes in destroying, altering, or suspending the activity of any morbific matter that may have been introduced with the cream into the several dishes. But what if next day's "cream" retained more than other dishes the original powers of the 4 o'clock cream; or contained them developed or redeveloped by the lapse of 20 hours? Unfortunately no answer can be given to these queries. But the suppositions they contain are not unlikely suppositions, and their truth would give a coincidence, crucial and all but absolute, between the distribution of scarlatina and the distribution of 4 o'clock cream to the several individuals who were in this South Kensington house on June 9th.

The ices on the evening table were not made in the house. The "creams" that were on the dinner table were not on the supper table. Other "creams," made at the same time, were on the supper table.

The servants were not questioned as to which of the two creams they may have tasted, as it was thought those engaged in preparing dinner could not be expected to have any differential knowledge. Incidentally it was heard that the lady's maid partook on the 10th June of the "cream" that was on the lunch table that day.

Upon this evidence, such as it is, the relation of the present outbreak of scarlatina to cream must stand or fall. The earlier evidence showed a considerable probability that the disease was spread by some article of food or drink, and the present evidence shows that the particular article may not improbably have been the cream supplied to this house at 4 o'clock on the day of the party.

The inquiry is next concerned with the circumstances under which the 4 o'clock supply may have become harmful. As I cannot attach importance to the notion (mentioned on a previous page) that the extra cook had her hands peeling on the day of the party, I proceed to tell what I was able to learn of the circumstances of the dairies. Mr. N., whose dairy furnished the habitual milk supply, and on June 9th the greater part of the cream supply to the A. family, had had no scarlatina in his house or among his men; nor, he told me, had there been any at his Hampshire farm. His customers living mostly in the South Kensington neighbourhood did not appear in the course of the inquiry (from the information of the Medical Officer of Health or otherwise) to have had any special scarlatina, if any at all, among them. Mr. M., whose dairy furnished through Mr. N. the distinctively dinner supply to the house of the A. family on June 9th, was then visited. He received me with perfect frankness and gave me all the facilities I could desire. His dairy is about a mile from the house of the A. family, in the sanitary district adjacent to that of which South Kensington forms a part. Inquiry here was threefold: As to any

special prevalence of scarlatina among the ordinary customers of Mr. M. ; as to any scarlatina in his household or milkmen ; and as to the health of his cows.

As to prevalence of scarlatina in customers, some curious facts have come out. The circumstsnces of all 400–500 book-customers could not of course be ascertained ; but the Medical Officer of Health of Mr. M.'s district caused inquiry as to scarlatina to be made at 147 houses in the immediate neighbourhood of the dairy with the result of finding cases of scarlatina or sore throat (during the month of June, but essentially at the beginning of the month), in 44 per cent. of them ; whereas, out of other localities of this district, the street where most scarlatina had been heard of gave out of 60 houses only 13 per cent. as having had scarlatina or sore throat during the month.

This special incidence on Mr. M.'s neighbourhood has an undoubted interest ; but its connexion with Mr. M.'s dairy is found on further inquiry to be obscure. The 147 houses are in a certain square, in a street leading out of it, and in a second street where Mr. M.'s dairy is. Of the 57 houses of the square, 41 were on Mr. M.'s books and 16 were not ; of the 41, 53 per cent. had scarlatina or sore throat in them ; of the 16, only 12 per cent. So that the incidence on the houses known to be supplied by Mr. M. was more than four times that on the houses not known to be supplied by him. But the street leading out of the square has 38 houses, 17 on Mr. M.'s books, 21 not ; of each group 47 per cent. had cases of scarlatina or sore throat, an exactly equal incidence. And the street where the milkman lives has 52 houses, 31 on Mr. M.'s books, 21 not ; of the former 48 per cent. had case of scarlatina or sore throat ; of the latter 33 per cent., the difference of incidence being less than as $1\frac{1}{2}$ to 1. It is true that the inquiry failed to bring out the facts with the precision that was to be desired. On the one hand, comparison of the scarlatina with houses taking Mr. M.'s milk was only made in regard of those houses in which book-customers lived, such of the houses as obtained ready money supplies by sending round to the dairy not being included. On the other hand, in regard of all those houses (of which there were many) occupied by more than one family, there is no evidence that it was the family that took Mr. M.'s milk that suffered from the current ailment.

An outbreak of these proportions, occurring in this sudden fashion, is itself an exceptional circumstance ; and such further particulars of it as were learnt for me may here be noted. The cases of sore throat and scarlatina occurring during June (with which some days at the end of May should probably be included) numbered in all 175, and were heard of in 64 of the 147 houses in the square and two streets ; and of the 175 attacks, 56 were spoken of as scarlatina, and 119 as sore throats ; of the latter, however, some are known on medical evidence to have really been scarlatina, and 27 of them were in 10 houses where there was also recognised scarlatina. There was an unusual prevalence of erysipelas in this same district, and some of the sore throats may possibly have been erysipelatous in nature. Of the 56 recognised scarlatina attacks, 47 occurred before the end of the first week of June, in 22 different houses, a whole family being in some instances attacked nearly simultaneously. Of the 119 " sore throats," 83 occurred before the end of the first week of June in 34 different houses, here again a whole family being frequently attacked nearly on the same day. There were thus in the course of a week or two, 130 cases of scarlatina or sore throat, and it is a remarkable circumstance that from this large number of cases there was no extensive spread of the disease ; up to the end of June only 45 other cases of scarlatina or sore throat being heard of in this square and two streets ; the prevalence of scarlatina in the district generally (so far as death-registers show) being meanwhile on the decrease. Another noteworthy circumstance is the small mortality of the outbreak, a

act that has to be noted in connexion with that mildness of disease that caused some cases, really scarlatina, to be considered as mere "sore throat," and that in many other cases allowed of no doctor being called in. If there were only 56 cases of real scarlatina, however, three or four deaths would be expected to occur among them, but in fact there was but one death from scarlatina or any similar disease in these three places during the 10 weeks ending July 31st. In these respects, in comparative absence of diffusion and in mildness of attack, the outbreak in the neighbourhood of Mr. M.'s dairy corresponded with that which forms the subject of this report. Further, it deserves mention that one case of the "sore throat" prevailing hereabouts was of a nature to suggest, to a practitioner residing in the neighbourhood, that tracheotomy might become necessary.

As to scarlatinal disease among Mr. M.'s household or milkmen, almost nothing could be heard of. After much questioning in a variety of directions, the only hint of such disease among these people was that a boy employed to milk the cows and carry out milk, lodging in a house where there was no scarlatina before or for some time after, but whose mother, remarried and living in another street, had scarlatina in her family in May, went on May 10th to a doctor for a sore throat. The doctor says he had no rash, and that his fauces were ulcerated. He prescribed a gargle, and repeated it on the second and only other occasion of his seeing the boy, on May 13th. The boy says he had not had scarlatina when young. When I examined the boy's hands on June 21st they were not desquamating, though the tips of the fingers looked tender.

As to disease in any of the cows at Mr. M.'s dairy, I have the advantage of Professor Brown's authority for saying that in the middle of June there was none. On a visit which he then made with me to the dairy, the animals were found to be in typical health.

Finally, the evidence which I have adduced in this report does not conclusively demonstrate the cause of scarlatina in this South Kensington outbreak. All that can be said is that the distribution of the disease is wholly unaccounted for, unless infection of a particular cream supply accounts for it. I believe the failure to get more definite evidence has been owing to the complicated nature of the conditions that had to be investigated. I should hope much from the prompt investigation of future cases that may bear a general resemblance to the foregoing, more particularly if they occurred under the simpler circumstances of a rural district. Already two or three instances, having many points of resemblance to this South Kensington outbreak, of scarlatina apparently spreading from dinner tables, have been met with in London since this inquiry was begun. Concerning them I have only to record in this place that they throw no light on the causation of the outbreak which is the subject of this Report.

No. 7.

App. No. 7.

Memorandum by Mr. Netten Radcliffe on the Modern History and Recent Progress of Levantine Plague.

On Levantine Plague, by Mr. Netten Radcliffe.

England and Europe, the latter half of the 17th century. 1665–1679.

Plague, which for an undetermined period had prevailed in England, either as a continuously present disease or as a series of frequently recurring epidemic invasions, after the great outbreak of 1665 quickly subsided and became extinct. In the year named (1665), according to the Bills of Mortality, it caused in London, which is supposed to have then had a population of about half a million persons, 68,596 deaths; in the following year (1666) 1,998 deaths; and in the subsequent 13 years (1666–1679) 81 deaths. After the year 1679 no death from plague was recorded in the Bills of Mortality. In the year 1704 the name of the disease was omitted from the Bills, and it has not since had a place in them.

The great outbreak of plague in this country in 1665 was part of a general diffusion of the disease, common probably to the countries lying east of the Mediterranean, to Europe, and to Northern Africa. In parts of Central, Southern, and Eastern Europe the disease was still prevalent as the century drew to a close, and early in the following century (the 18th) it again became active and spread very widely in Continental Europe, the countries of the Levant, and in Northern and North-Western Africa. As the century advanced plague died out in Western and Northern Europe and in the greater number of the countries of Central Europe, but in Eastern Europe the disease continued into the present (the 19th) century.

The 18th century.

From the period of cessation of plague in this country in the 17th century to the termination of the 18th century, the phenomena of the diffusion of plague in Europe, as far as the imperfect data existing on the subject permit a judgment to be formed, indicate a gradual diminution of the area within which the malady could retain its activity. The better recorded phenomena of diffusion of the disease within the present century show such diminution proceeding at a greatly augmented rate until the apparent extinction of the malady over the whole area of its previous range of prevalence in Europe, Northern Africa, and the countries east of the Mediterranean, the disease apparently at no time presenting any amelioration of its accustomed virulence.

The 19th century. 1800–1824.

In 1812–14, plague became widely diffused in the Levant, in the districts bordering the Lower Danube, in Transylvania, in Asia Minor, and in Armenia, also in Northern Africa, west of Egypt. This diffusion continued in one district or another within the area of dispersion throughout the next 20 years, but during the whole of that period there was no extension into Central, Northern, and Western Europe. Hardly had the diffusion beginning in 1812 come to an end (if, indeed, it had wholly ceased) when plague again became active in the Levant. Greatly as the area of prevalence had diminished in the previous diffusion, as compared with still earlier diffusions, the area was still further lessened in the diffusion which commenced in 1834–35.

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* The orthography of Keith Johnston's *Index Geographicus* has been, as a rule, followed in the spelling of proper names in the text of this memorandum. In dealing with numerous reports of many writers, each of whom uses apparently his own system of orthography, I may not always have secured uniformity, and where I have had occasion to quote I have retained the orthography of the writer; but, little difficulty will be experienced, I believe, in recognising places and communities referred to, although they may appear in various orthographical guises.

This latter diffusion, the last from which any part of Europe suffered, was chiefly confined to the Turkish dominions in Europe and Asia nd to Egypt. The malady extended to the towns and districts of Vallachia bordering the Danube, and also into Greece, but no other ountries in Europe contiguous to Turkey were affected. In Africa, he malady appears to have been limited to Egypt. Five years after he commencement of this diffusion, namely in 1839, plague disappeared rom Constantinople, and two years after its cessation on the Bosphorus t died out in the European provinces of the Porte.

On Levantine Plague, by Mr. Netten Radcliffe.

1834-1841.

Cessation of Plague in Europe, 1841.

While plague was thus becoming extinct in Europe, it again became ctively diffusive in Egypt, Syria, and Palestine (1840–41.) The isease was apparently not less virulent in this diffusion than in previous iffusions, but except, probably, some dispersion into parts of Asia linor, it did not spread beyond the countries named. With the ermination of this diffusion plague vanished from the East. No case f the disease is known to have occurred in Syria, Palestine, and Asia linor since 1843, nor in Egypt since 1844.

1841-44.

Cessation in Syria, Palestine, and Asia Minor, 1843.

Cessation in Egypt, 1844.

For centuries Egypt and the countries lying to the east of the lediterranean had been regarded as the birth-place of the several iffusions of plague which had spread over Europe. In these countries he disease lingered longest and was latest to disappear during that radual decrease of the area of prevalence, which observed in this ountry after the great outbreak of 1665, came to an end in Egypt with he apparent extinction of the disease, in 1844.*

The Re-appearance of Plague. Western Arabia, 1853.

Fourteen years after the cessation of plague in the countries where is believed to have previously prevailed from time immemorial, the isease again appeared in the basin of the Mediterranean, within the rovince of Tripoli, the easternmost state of Barbary. During the nterval no previous prevalence of plague had come to knowledge, but is now known (the fact having been ascertained in 1874) that plague ad been present in the highlands of Western Arabia in 1853. In that ear an outbreak took place in the mountainous region of the Assyr istrict, North Yemen, part it would seem of a wider diffusion of the isease in Arabia. The mere fact appears to have been alone ascertained uring an inquiry made under the direction of the Ottoman Government elating to the appearance of plague in the same district in 1874.†

Bengazi, Tripoli, 1858-59.

In 1858, about the middle of April, plague broke out in the province f Bengazi, Regency of Tripoli, North Africa. This province (the ncient maritime region of Barca, including the Cyrenaica or Pentaolis), celebrated of old for the fertility of its highlands and of its ttoral, affords pasturage for many flocks and herds and yields rich rops and grains, notwithstanding an imperfect and partial cultivation f the soil. The population is chiefly nomadic, frequenting the igher grounds and the table-land of Merdj during the hot season, hen the pasturage in the plains has been parched up and withered, nd returning to the low-lying tracts after the autumnal rains, when ey have become covered by luxuriant vegetation. The fixed popula-on is principally accumulated in the only two towns of the province, amely, Bengazi (built on the site of the former Berenice and more

* See as to prevalence of plague during the early part of the 19th century, Dr. avin Milroy's "Sketch of the Geography, &c. of the Plague during the Present entury" (the British and Foreign Medico-Chirurgical Review, Vol. XXXIII. Vol. I. 1864), p. 463; also Hirsch's *Handbuch des historisch-geographischen Pathogie*, Vol. I., p. 197.

† See on this subject a letter of Dr. Dickson's, p. 54.

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remote Hesperides), and Derna (built on the site of the former Darnis), each of which towns contains about 12,000 inhabitants. Villages formed by small groups of miserable huts exist on the littoral and in the interior, and several Arab monasteries; and certain Arab tribes occupy cave dwellings.

Plague, in 1858, first appeared in the province of Bengazi, in an Arab encampment consisting of 30 huts, pitched at the time eight hours distant from the town of Bengazi, in the plain of Amalisgalen Fiddaar. The disease was next observed in the town of Bengazi at the beginning of May, and afterwards it spread throughout four of the five districts into which the province is divided, namely, Bengazi, Derna, Gharb, and Chark, affecting both the nomadic and the fixed populations. Derna was attacked at the close of May or beginning of June, the development of the malady there following upon an importation of a case from Bengazi; and Merdj, the chief place of the district of Gharb, a village situated on the Cyrenaic plateau, and having a fixed population of 100, together with a garrison of 100 soldiers, was attacked about the 15th June. The district of Auldja, which has a very scanty fixed population living in the midst of sandy desert escaped the outbreak.

The disease was most prevalent and the loss of life from it was greatest during the year 1858, but it continued into the following year, disappearing from the towns of Bengazi and Derna in June 1859. The number of attacks which occurred is not known, but the mortality among the sick who came under observations was about 40 per cent., and the total deaths were estimated approximatively to have been 4,000.

This appearance of plague in the province of Bengazi had been preceded by four years of drought and consequent failure of crops. Each successive year the miseries arising from dearth had increased. The greater part of the flocks and herds were destroyed from want of food and the mortality among horned cattle was augmented by a fatal epizootic which attacked them. Plague appeared when the suffering of the population from famine were greatest.*

Persian Kurdistan, 1863.

In November 1863, the Ottoman quarantine physician at Bayazid on the Turco-Persian frontier, reported the occurrence of a fatal bubonic disease resembling plague in the district of Maku,† Persian Kurdistan. The nature of this disease and the conditions under which it was developed were investigated by Dr. Rossi, the inspector of quarantine at Erzerum, under instructions from the Ottoman General Board of Health. Dr. Rossi was accompanied during his investigation by Dr. Auriema, Dr. Pandeli, Aali Effendi, director of quarantine at Bagajid, and Miza Aga, a member of the Municipal Court at Bayazid. The result of his inquiry is thus described in a report by Dr. Dickson to Her Majesty's Representative at Constantinople, dated 29th December 1863.

"Dr. Rossi examined eight cases affected with this malady and the symptoms presented by them were as follows:—The invasion of the complaint was marked by fever of a burning nature; lassitude and great debility; dejected aspect; vertigo; headache; intellect more or less disturbed; tongue dry

* See on this outbreak a report by Dr. Bartoletti, who was commissioned, in conjunction with Dr. Amadeo, to investigate it; and various reports regarding the outbreak made by Dr. Fauvel, who was the sanitary representative of France in Constantinople at the time (and which include summaries of Dr. Barozzi's reports, who was sent to Bengazi by the Ottoman Government early in 1859), published in the *Recueil de Travaux Comité Consultatif d'Hygiène publique de France*, tome 4e, pp. 151–212.

† The town of Maku (province of Azerbijan) lies in the extreme north-west of Persia.

vered with white fur; constipation; and darting pain with swelling either the axilla or in the groin. These were followed from the second up to the th day, by the appearance of one or more sloughing boils or carbuncles on at side of the person which had been affected with the glandular pain and elling. In two instances the sides of the neck were painful, followed on e third day by a sloughing boil on the cervical vertebræ. On the appearance the boils, the axillary and inguinal swellings subsided. In one case the anifestation of a carbuncle was followed by diarrhœa. When the boils supputed, the patients generally felt relieved.

"The population of Maku is estimated by Dr. Rossi at 1,500 inhabitants: f these about 50 were said to be actually laid up with the distemper. A onth before, double this number were ill; but the epidemic had considerably minished after the fall of snow and lowered temperature.

"The epidemic originally declared itself in the month of September among ie tribe of Jellali who reside at 'Ak-Ghiol,' 11 hours distant from the fron-er, opposite to Erwan, and subsequently appeared in the town of Maku. was asserted that no deaths ensued from it, but Dr. Rossi was impressed ith the idea that the Persians were endeavouring to conceal the truth from im. In the villages of 'Akdahan' and 'Danali,' several deaths had ccurred and come to his knowledge. The distemper still prevailed at Ak-Ghiol,' and Aali Khan, the ruler of Maku has prohibited the admittance nto his territory of those Koordish tribes who are affected with the disease.

"Dr. Rossi considers the epidemic to be one of *true plague*, and he attributes s manifestation to the severe murrain existing at Maku, which infects the hole district with putrid emanations arising from the unburied bodies of ead cattle, the use of diseased meat as food by the inhabitants, and poverty, wing to the failure of the crops. . . . .

"The Board of Health, neither satisfied with the inspection made by Dr. ossi, nor convinced that the distemper reigning at Maku is really the plague, ave ordered Dr. Bimsenstein, their Sanitary Agent at Teheran, to proceed ithout delay and take up his residence at Maku, and report from time to time n the nature and progress of this malady."

Dr. Bimsenstein visited the district of Maku in January 1864. His nquiry included the town of Maku and 25 villages, but not the nomadic ribe among whom the disease first appeared. He discovered one case nly of bubonic disease, which he believed to be plague, the patient, a oung man, being convalescent at the time. As the general result of his nvestigation, Dr. Bimsenstein, in a report dated the 15th February 1864, rrites:—"Pour moi il n'y a pas de doute que la peste y avait existé parmi les nomades et que le bruit qui courait alors de l'existence de cette maladie était bien fondé."*

The Lower Euphrates, 1867.

Eight years after the outbreak of plague in the province of Bengazi, nd four years after the reported occurrence of the disease in north-vestern Persia, the malady appeared among the Arabs inhabiting the Hindieh marshes on the Lower Euphrates. These marshes lie on the vest bank of the river in close proximity to the ruins of ancient Babylon, and they cover a district measuring about 60 miles in length rom north to south, and 20 miles in breadth from east to west. Into he northern extremity of these marshes opens the Hindieh canal; and heir southern extremity communicates with the great inland lake known as the Sea of Nedjef (the Bahr-i-Nedjef). The Hindieh canal as a navigable channel which begins, according to Mr. Kennett Loftus, bout two miles below the Khan at Musseib, and about 16 miles above

* Sir Samuel Baker, in his account of the discovery of the Albert N'Yanza, describes a pestilential outbreak of disease, observed on his return journey, at Khartoum, late in 1864 and at the begining of 1865. He writes of it as "plague" or "malignant typhus." None of the symptoms most characteristic of the former disease are mentioned, and the latter designation, so far as the description admits of a judgment being formed, would seem the more accurate one. (*The Albert N'Yanza Great Basin of the Nile*, Chaps. 18 and 19.)

the existing ruins of Babylon. It follows the course of an ancient canal constructed for the relief of the low-lying grounds east of the stream during its periodical floods, and for purposes of irrigation, and derives its present designation from an Indian prince who, a century and a quarter ago, opened out the channel which had then become blocked. The mouth of the Hindieh is dammed so as to regulate the amount of water passing into it, but at times, in exceptional floods, the dam is carried away. The vast body of water which then passes through the canal, converts the whole district lying between its outlet and the Sea of Nedjef into an inundation, as also the district laying between the outlet of that sheet of water and Samava. When the river has fallen to its usual level, the mouth of the Hindieh remaining open, a deep stream 180 feet wide passes along the canal into and through the marshes to the Sea of Nedjef, and by this route and the streams flowing from the Sea of Nedjef into the Euphrates merchandise is is conveyed from Hillah to Basra. Indeed, along this route, through the Hindieh marshes and the Sea of Nedjef and its outflow, it would appear that at the present time navigation can alone be maintained between the Upper and Lower Euphrates. For the volume of the river is so greatly diminished by the amount of water passing through the Hindieh canal and certain other canals that below Lamlum the stream in the proper channel is entirely absorbed in the extensive rice-fields which exist there.*

West of the Hindieh marshes is the Syrian desert, and to the north-west, on the skirt of the desert, within eye-shot, Kerbella (Meshed Hussein), and to the south overlooking the Sea of Nedjef, Nedjef (Meshed Ali). Nedjef, the burial place of Ali, the fourth Caliph, and Kerbella the burial place of his two sons, Hussein, "the Martyr," and Abbas, are sacred to the Shiah Mahommedans. They form a centre of pilgrimage, second only in importance, among the Mahommedans, to that of Mecca. To both cities annually resort many thousands of pilgrims from Persia, the Mahommedan districts of Caucasia, and from Hindostan, carrying with them great numbers of corpses in all stages of decomposition for burial in the sacred soil. Pilgrims from Caucasia, northern, central, and eastern Persia, travel to their destination by way of Bagdad and thence to Musseib (crossing the river at that place), and Kerbella, or to Hillah (traversing the stream there) and through the Hindieh marshes by boat to Nedjef. Pilgrims from Southern Persia and Hindostan ascend the Euphrates to Samava, and then pass along the principal outlet of the Sea of Nedjef, the Shat-el-Atchan (the western branch of the Euphrates, as it has been termed) and cross the Sea of Nedjef to Nedjef. Many pilgrims, after performing their devotions at Nedjef and Kerbella, travel onwards to Mecca, by way of central or northern Arabia or Syria. Others first perform the pilgrimage to Mecca, visiting Nedjef and Kerbella on their return homewards. In 1871 a caravan of pilgrims bound for Mecca, which had left Nedjef at a time when cholera was prevalent there, and travelled by the northern route through Arabia introduced cholera into Haïl, the chief town of the Jebel Shomer district. Thence the disease was propagated to Medina, Mecca, and the east coast of the Red Sea; and in the following year (1872) it spread into Nubia.

The Hindieh marshes are inhabited by many communities of Arabs of the Beni-Taraf tribe. These live in villages erected upon the islets within the marshes or upon the outskirts. The villages, for the most

* See Surgeon-Major Colvill's Report on Plague in Mesopotamia, 1875. Note, p. 18.

SEATS OF PLAGUE
1867, 1870-71 & 1873 74-75
Districts infected
AFGHANISTAN

This Map is based upon a late survey in the possession of the Indo-rivers. The position as also that to Mr Colvill of the Bar Kitbush of certain places and of the Ker Feldsh or the site of Lamlum where the steamer ruptured during the winter channel of the Euphrates is laid down by Authorized surveyors also

part are formed of huts, or rather "dug-outs" hollowed in the wet soil, and roofed with reeds covered with matting or thickly plastered with mud. The wretchedness of these dwellings is augmented by the indescribably filthy habits of the occupiers in persons and surroundings. Rice is largely cultivated by the different communities, but not to the exclusion of other grain, and they possess large flocks of sheep and herds of cattle. The men of the Beni-Taraf tribe are described as remarkably well-limbed, active, and athletic. They and their families live chiefly upon rice (eaten it is to be presumed, although this is not stated, with sheep's-tail fat, as pillaff), bread, and dates, little flesh meat being consumed. Recent medical visitors to the marshes have stated that the communities are singularly free from signs of marsh poisoning. On the other hand malarial fevers (occasionally pernicious) are spoken of as occurring in the district. Very probably the state of health of the communities varies greatly with the state of the marshes. When the mouth of the Hindieh canal is freely open, the marshes are in fact an inundation with a current moving steadily towards the Sea of Nedjef; when it is partially or wholly closed they may become stagnant swamps, the water of the canal being retained within the various irrigation channels.

The Hindieh marshes as observed from the summit of Birs Nimrúd, are thus described by Mr. Kennett Loftus (*Travels and Researches in Chaldæa and Susiana*) who visited the locality in 1854:—

"The view from the summit of the Birs Nimrúd is very extensive, and its utter desolation has been the theme of frequent observation. No one can stand there and survey the scene around without being struck with the literal fulfilment of Isaiah's prophecy:—'I will make it a possession for the bittern, and pools of water; and I will sweep it with the besom of destruction, saith the Lord of Hosts.' Spreading out like a vast sea upon the north and west is a marsh, which all the labours of the ancient and modern rulers of the country have never been able to subdue. In certain seasons the waters of the Euphrates rise above their ordinary level and flood the whole surface of the low lands of Chaldæa, confirming every word of the prophet.

"Bordering upon this marsh a few spots attract the eye and relieve the long level of the horizon. Due south stands the little tomb of the prophet Ezekiel, and at the distance of 50 miles, in the mirage of early morning, may be discerned the mosque of the sainted Ali, glistening like a speck of gold as the beams of the rising sun play upon its surface. Nearer at hand, on the north-west, are the twin domes of Kerbella, the burial place of Ali's slaughtered sons. The edge and islands of the marsh are at times dotted with encampments of Khuzeyl Arabs, and with the telescope may be distinguished their numerous flocks of sheep and camels, while the hum of busy voices can be distinctly heard a distance of full six miles across the waters.

"From the Birs Nimrúd southwards a road runs along the raised bank, which here in a measure restrains the marsh within bounds. A succession of large canal courses, now dry, are crossed during a ride of 12 miles to the little town of Keffil, which, from its want of luxuriant trees and vegetation, looks dull and sombre in the extreme, a fitting place for the sepulchre of a captive prophet in a strange land. There have been trees at some time or other, as a few stunted palms bear witness, but, like the town itself, they have witnessed more flourishing times. They are ludicrous specimens of their race, and stand with their branches projecting straight upwards into the air, giving them the appearance of gigantic brooms. . . ." (pp. 33–34).

"• • • In order to reach Meshed Ali, it is necessary to cross the marsh; for this purpose boats are always to be procured at Keffil. They are heavy, clumsy vessels, constructed of Indian teak, about 40 feet in length, with high pointed prows and sterns, and flat bottoms, for enabling them to skim over the shallows. Each is guided by two nearly naked Arabs, one of whom manages the cumbrous and primitive rudder, while the other attends to a huge lug-sail, if such a term can be applied to a patchwork of every shape and colour, filled with innumerable holes.

"The stream flows, at the rate of four or five miles an hour, through a continuous rice field, which is prevented from being completely overflooded by means of dams constructed of stakes and reed matting. Sometimes, when the rise of the Euphrates exceeds its usual level, the country is a vast inundation. On such occasions whole families of Arabs, with their frail dwellings of reeds and tents, are swept away in a single night. These calamities are but too frequent. Upon a few elevated spots small mud forts serve as citadels for refuge in case of inundation or attack. The Arab inhabitants of these marshes are a fine manly race, and their noble forms are particularly striking. Their half-naked and deeply-bronzed bodies, nourished by scanty fare, show every muscle to advantage as they propel their vessels with long poles in the shallows against the wind or stream, dexterously running along the edge of the boat. The keffieh, or head-dress, is useless among these marshes, for the long, thick, streaming hair of the Khuzeyl Arab acts as the most natural covering, and is admirably adapted for keeping off the rays of the sun.

"In sailing along, every now and then we encountered a noisy party in a crowded boat, who gazed with wonder, not unmixed with alarm, upon the European fleet. All appeared life and activity around us in those fens, the men not languidly smoking their pipes like the dwellers in cities and loungers in bazaars, but busy at their daily employments, as agriculturists should be. The women were engaged about their tents with duties not less arduous than those of the stronger sex. Notwithstanding their labour and activity they are evidently in a wretched state of misery, and ground down by heavy exactions. . . ." (pp. 38–39).*

The same author writes of the Hindieh canal (which he suggests follows the line of the ancient Pallocopas), and of the Sea of Nedjef as follows:—

"The mouth of this interesting canal is situated about two miles below the Khan at Musseib, and about 16 miles above the commencement of the existing ruins of Babylon, at a point where the natural channel of the Euphrates makes a slight eastern bend. When greatly flooded the violence of the stream frequently breaks down the artificial barriers erected to regulate the influx of water, and enlarges the entrance of the Hindieh. Immense sums of money are expended by the Turkish Government in rebuilding, repairing, and strengthening the dam, because the river has a tendency to quit the Babylon channel and to flow westward into the marshes, as in the days of Alexander. The natural effect is to deprive the eastern side of the Euphrates of its due irrigation, by reducing all the canals below the point of bifurcation; the villages become deserted and the fields uncultivated. On the western side the rice grounds of the Khuzeyl Arabs are overflowed, and cultivation is entirely out of the question. The chief revenues of Baghdad being derived from these regions, it is of the utmost importance that the equilibrium of the two branches of the Euphrates should be properly cared for.

"Soon after the accession of Abdi Pasha to the government of the province, like all his predecessors, his attention was directed to this subject. The force of the stream, caused by the extraordinary rise of the river, had carried away every trace of the former dams, and enlarged the mouth of the Hindieh to such an extent that the Euphrates bid fair to disappear into the western marshes. He therefore cut a new channel, 120 feet broad, at a short distance above the bifurcation, which relieved the pressure and enabled him to effect the building of a new and strong dam of osiers, reeds, and earth at the mouth of the Hindieh, while the quantity of water admitted into the new cut was regulated by two solid brick piers with sluice-gates 80 feet wide.

"Notwithstanding all this expense and trouble, the river in 1854 overcame all obstacles, and once more regained possession of the marshes. Flowing

* Mr. Layard describes the scene late in 1849 from Birs Nimrud, looking towards the marshes, as follows:—"In the midst of the swamps could be faintly distinguished "the mat huts of the Kazail forming villages on the small islands. The green "morass was spotted with flocks of the black buffalo. The Arab settlements "showed the activity of a hive of bees. Light boats were skimming to and fro "over the shallow water, and women urged onwards their flocks and laden cattle." —(*Discoveries in the Ruins of Ninevah and Babylon.* 1853, p. 500.)

southwards a few miles a deep stream 180 feet wide, with banks 10 or 20 feet high, the Hindieh enters and is lost in the great inundation extending on the north and west of the Birs Nimrúd, passes Keffil and the ruins of Kufa, and ultimately debouches into the great inland fresh-water sea of Nedjef.

"No modern traveller has yet succeeded in following the entire course of the ancient Pallacopas, but traces of its channel are still visible on the east of the town of Nedjef.

"The great sheet of water, the Bahr-i-Nedjef, extends 40 miles in a south-easterly direction, and at its southern extremity gives out two considerable streams, Shat-el-Khuzif and Shat-el-Atchan, which subsequently unite, and are known by the latter name. Further to the south, five large bodies of water have their origin from the Atchan, and, uniting, constitute the Huran. This, after flowing about 30 miles, eventually joins the Atchan, and the two rivers form what is called the western or Samava branch of the Euphrates. All the above branches are navigable when the mouth of the Hindieh is open, and it is by them that merchandise is conveyed from Busrah to Hillah. When the great annual rise of the Euphrates occurs, the whole region from the Bahr-i-Nedjef to Samava is one continuous inundation, called the 'Khor Ullah,' or marshes of God. Here and there it is dotted with thousands of small islands, separated from each other by an infinity of streamlets. It was amid the innumerable channels of these *Paludes Babyloniæ* that Alexander was overtaken by a storm and all but lost during his sail down the Pallacopas.

"It is only when the mouth of the Hindieh is opened by the destruction of the dams that the modern traveller is enabled to see the *Paludes Babyloniæ* as Alexander saw them. When, however, the Hindieh is closed effectually for a time, the Khuzif and Atchan cease altogether to exist, and the town of Samava is supplied by two small canals derived from the Hillah branch of the Euphrates, near Diwanieh. Such was probably the case during the labours of the officers in the Euphrates expedition under Colonel Chesney, as the streams flowing from the Bahr-i-Nedjef are not laid down on any map. Instead of them, however, there is the course of an extinct river-bed passing east of the Bahr-i-Nedjef to Semava, which may represent the Pallacopas of Alexander in a portion of its course" (pp. 42–46).

Among certain of the villages amidst the Hindieh marshes, in 1867, after an excessive flood of the Euphrates and inundation of the marshes, plague which was believed to have disappeared from Mesopotamia for 33 years reappeared. The population of the Hindieh district at this time was estimated, officially, at 50,000, but the inhabitants of five villages only were ascertained to have been affected by the disease. The total inhabitants of these villages did not exceed 1,000, and the deaths among them from plague, it is believed, were not less than 300. The disease ceased in June. The symptoms of the malady, as summed up by one of the Sheikhs of the infected villages to Dr. Paduan, the Superintendent of the Ottoman Sanitary Administration in the pashalik of Bagdad, were, "ardent fever, intense thirst, delirium, swellings in "the parotids, in the armpits, and in the groins, then black circles "appeared upon various parts of the body, ending in sloughs." In one case investigated by Mr. Colvill, Surgeon to the British Residency, Bagdad, there had been bloody vomit; in another case seen by him, diarrhœa with bloody stools was stated to have been an early symptom.*

* Accounts of this outbreak of plague, from which several of the details in the text are taken, have been published by Dr. E. D. Dickson, the Physician to H.M. Embassy, Constantinople (*Transactions of the Epidemiological Society of London*, Vol. 3, Pt. 1, p. 143); by Mr. Colvill (Sanitary Report on Turkish Arabia, Transactions of the Medical and Physical Society of Bombay, 1871, p. 49); by Dr. Tholozan in two monographs (*Une Epidémie de Peste en Mesopotamie en* 1867, Paris, 1867, and *Histoire de la Peste bubonique en Mesopotamie*, Paris, 1874; and by Dr. Naranzi, Secretary to the General Board of Health of the Ottoman Empire (*Rapport sur l'Epidémie de Hindié dans l'Irak-Arabi, en* 1867). Dr. Naranzi, under instructions from the Board, visited the scene of the outbreak several months

Persian Kurdistan, 1871.

After this occurrence of plague in the Lower Euphrates nothing more was heard of the disease until the year 1871, when it appeared in Persian Kurdistan. This appearance was investigated at the time by Drs. Castaldi, Paduan, and Wortabet, the Ottoman sanitary physicians resident at Teheran, Bagdad, and Sulcimanieh respectively, and by Dr. Schlimmer, of Teheran. These gentlemen were not able to penetrate into the more remote district where plague had first broken out, the surrounding communities refusing to allow them to pass and threatening them with death if they made the attempt. But they were enabled to study the disease at Bana and other places on the outskirts of the area which had become infected. Dr. Castaldi's official report of the results of his inquiry made to the General Board of Health, Constantinople, has been published;* and Dr. Schlimmer has also published an account of the results of his investigation.† After the cessation of the outbreak, the district which had been infected was visited, under instructions from the Governor of Georgia, by Dr. Telafous, the Quarantine Director at Akhalsikh, on the Russo-Persian frontier. He was able to visit every part of the district, including the villages where plague is believed to have been earliest developed. His inquiries substantially confirmed the information which had been furnished to Dr. Castaldi respecting the beginning of the outbreak.

Plague in this outbreak in Persian Kurdistan appears to have first shown itself at the end of autumn 1870 or the beginning of the winter of 1870–71, on an elevated table-land lying south-east of Lake Urumiah, between the head waters of the rivers Jagatu and Tatawa, both of which streams flow into the lake named. The district had last before suffered from plague in the epidemic of 1829–35. The villages attacked not only within the locality of first appearance, but also in neighbouring localities to which the disease extended, including the town of Bana (Berozeh), are according to Dr. Telafous built at altitudes above the Black Sea of which the lowest (Uchtepé) is 4,540 feet, and the highest (Arbanos, where the disease seems first to have become active), 5,870. Bana has an altitude of 5,470 feet; and Akjivan, where the nature of the disease was first recognised, is 5,240 feet.

The villages earliest attacked are situated in the district of Mikri. The disease is believed to have originated in a hamlet named Djoumou-

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after the cessation of plague, and as the results of the inquiry he then made, he came to the conclusion that that disease had not been plague, but a malarial typhoid fever, which he designated *typhus loimoïde non-contagieux*. He was chiefly influenced in arriving at this conclusion by the circumscribed prevalance of the disease, which he held to be inconsistent with a belief in the contagiousness which is considered to be one of the characteristice of *bubonic* plague. Dr. Paduan and Mr. Colvill, both of whom had visited the infected district before the disease had ceased, and had seen cases in various stages of its progress, were both convinced that the malady was bubonic plague. The opinion of Dr. Paduan on this subject has the weight obtained from a previous acquaintance with the disease, before its apparent cessation in Mesopotamia and elsewhere in the East. The unquestioned appearance of plague in a contiguous district of the Lower Euphrates in 1874, is regarded by the Ottoman General Board of Health, which had previously been doubtful on the subject, to be confirmatory of the conclusion arrived at by Dr. Paduan and Dr. Colvill. (See note to this effect in Dr. Castaldi's Report on Plague in Irak-Arabi, 1873–74, p. 38.)

* La Peste dans le Kurdistan Persan. Rapport du Dr. Castaldi, Constantinople, 1872.

† Contribution à l'Historie de la Peste en Perse, Par Joh. L. Schlimmer, Teheran (lithograph), 1874.

Dr. Tholozan has discussed this outbreak in a *Note sur le developpement de la Peste Bubonique dans le Kurdistan en* 1871, Paris, 1871; and again in his *Histoire de la Peste Bubonique en Perse*, Paris, 1874.

chan (Gamishan), which is situated at an altitude of 6,600 feet, and which at the time of the appearance of plague contained six families. When this hamlet was visited by Dr. Telafous he found but one family in it, and he simply observes with respect to it that "from the local "characteristics he could discover nothing which would explain the "origin of the disease, the springs of water being very pure, the "inhabitants few, only six families, mountain air and severe winters." Arbanos, three miles distant from Djoumouchan, is described by Dr. Castaldi as being situated in an unwholesome marshy district where rice is largely cultivated. This village contained 25 families, among whom there were 77 cases of plague, 65 of which were fatal. Akjivan, in the same neighbourhood, a village of 150 families, among whom there were 160 cases of plague, 130 fatal, is described by Dr. Telafous as "built on an argillaceous calcareous soil, possessing many excellent "springs of water, but without any vegetation near the houses, the "cultivated tracts lying some distance from the village as likewise the "graveyard. The lanes and alleys between the houses were full of "filth, which is however the usual characteristic of the Kurdish "villages. The houses are not crowded together, nor do the walls of "one abut on those of another." The following descriptions of other villages early attacked by plague may also be quoted from Dr. Castaldi's report, the altitudes, population, and extent to which affected being taken from Dr. Telafous's report. Kananias (altitude 5,550 feet, families 15, attacks 12, deaths 8), "is situated at the foot of the "mountain in a small arid plain, not far from the river Jagatu. The "village is formed by half-a-score houses leaning one against another, "with low and contracted doors and windows. Before these houses "are heaps of ordure of every kind, and also of sun-dried cakes of "cow-dung used for fuel, there being no wood in the locality. This "combustible is piled up all around the village to a height higher than "the windows, and it is stored also in layers on the roofs of the houses. "Whatever is most afflicting in poverty, whatever is most revolting in "filthiness is accumulated, as if designedly, around these infected dens, "in the interior of which live or rather vegitate from 50 to 60 indi-"viduals, men, women, and children. The cultivation of some plots of "ground in the neighbourhood furnishes these unfortunates with in-"sufficient nourishment." Of Karava (altitude 5,650 feet, families 20, attacks 40, deaths 32), another early infected village, Dr. Castaldi says: "All that I have said of Kananias is equally applicable to Karava. "The same misery, the same filthiness, the same crowding together of "houses. In half-a-score of these foul hovels, veritable burrows, live "nearly 100 people."

The spring of 1870 had been one of extreme drought, and in the course of the year a fatal epizootic had occurred among sheep and ergotism among the people. The district, it is stated, escaped the disastrous famine which had affected Persia, beginning in 1870 and continuing throughout 1871; but with preceding murrain and ergotism it may be doubted, notwithstanding the statement of the official reporter to the contrary, whether the inhabitants did not suffer from actual privation in the winter of 1870–71. During the winter deep snow fell, and the villagers being shut in intercourse with each other and with the surrounding districts became impossible. Whilst the populations were thus snowed up, built in by the snow in the midst of the indescribable filth, peculiar to Kurdish villages, plague became active among the infected communities and almost extinguished several. When the spring enabled communications to be resumed between the infected villages and neighbouring villages and districts, plague spread

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abroad over a relatively limited area. It extended as far south as Bana, but before the close of the year it appears to have died out.

The disease as observed by Dr. Castaldi and his colleagues was characterised by ardent fever, the appearance of bubos in the armpits and groins, and on the neck, the occurrence of carbuncles in various parts of the body, and of petechiæ scattered generally over it. In the villages it spread from house to house in succession, and among families from one member to another, in fatal cases running a rapid course of from two to four days.

I subjoin Dr. Telafous's statement of the villages and towns affected in this outbreak, and of the losses occasioned by the disease in them. Dr. Castaldi mentions other places not included in Dr. Telafous's list, and his account of the attacks and deaths do not correspond with Dr. Telafous's statement. But Dr. Telafous's information being in every instance obtained upon the spot is probably the nearest approximation to the truth.

—	Names of Villages, &c	Number of Families.	Number of Persons attacked by the Plague.		Distance in hours from Akjivan.	Height in Feet above the level of London.	Height in Feet above the level of the Black Sea.
			Died.	Recovered.			
1	Akjivan - -	150	100	30	—	6,150	5,240
2	Gamishan - -	6	7	0	½	6,600	5,650
3	Arbanos - -	25	65	12	¾	6,720	5,870
4	Bibikend -	15	25	2	½	6,500	5,650
5	Chahardowli - -	60	60	20	¾	5,850	5,000
6	Sarab - - -	100	6	1	1½	5,900	5,050
7	Gök tepé -	25	10	0	2¾	Id.	Id.
8	Armeni boulak - -	200	125	20	2	Id.	Id.
9	Ak tepé - -	60	60	6	2½	6,000	5,150
10	Turcoman kendi -	50	130	20	3	6,150	5,300
11	Üch-tepé - -	200	200	50	3	5,790	4,540
12	Karava - - -	20	32	8	9½	6,500	5,650
13	Kananias - -	15	8	4	10	6,400	5,550
14	Bana (town) - -	400	63	56	20	6,320	5,470
	Total - -	1,326	891	229	—	—	—

1873-74.

After the appearance of plague in 1870–71 in Persian Kurdistan, vague rumours of the occurrence of the disease in Kurdistan from time to time gained currency in the East. None of these rumours were confirmed, but in the winter of 1873–74 and spring of 1874 the disease broke out in three localities widely separated from each other. It appeared in December 1873 among the Affij Arabs, occupying the marshes extending north and east of Diwanieh on the east bank of the river Euphrates, nearly opposite the scene of the outbreak of 1867. About the same time the disease appeared in North Africa among certain tribes of nomadic Arabs then encamped on the Cyrenaic plateau, in the province of Bengazi (Tripoli), within the area of the outbreak of 1858. A little later, if not contemporaneously, it broke out in the Assyr country, Western Arabia.

1873-74.—The Lower Euphrates.

On the east bank of the river Euphrates, opposite the southern extremity of the district occupied by the Hindieh marshes on the west bank, is the "Mighty Marsh," inhabited by the Affij Arabs, the first of a series of great marshes which extend to the junction of the

Euphrates with the Tigris. Opening into the northern portion of this marsh is the Dagarra Canal, a great irrigation channel of which the neglected and ruinous ramifications doubtless contribute to the formation of the Marsh. When the river is in flood the water pouring through this canal converts the marsh and the adjacent country with an extensive inundation. What has been said of the Beni Taraf Arabs and their habitations, means, and food, in the Hindieh marshes, applies equally to the Affij Arabs.

The following extracts are from Mr. Layard's description of the marsh occupied by the Affij Arabs. He visited the tribe at the beginning of 1850, approaching their district from the north :—

"We now came to the borders of those marshes which have now spread over the lower part of the Mesopotamian plains. As we ascended the lofty banks of ancient canals, over which our track continually led, we saw a boundless expanse of dark green, mottled with shadows by the wind, like the ruffled surface of a lake. It seemed as if the parched desert had been suddenly turned into pastures and fields of green corn. But we only gazed upon a vast bed of tall reeds bred by the wide spreading swamps, no less a sight of desolation, neglect, and decay, than the yellow wilderness. . . .

"We had sent one of our Affaij guides to inform Sheikh Agab of our approach. I had not been long seated in my tent when suddenly a number of black boats, each bearing a party of Arabs, darted from the reeds and approached the shore. They were of various sizes. In the bottom of some eight or ten persons sat crouched on their hams; in others, only one or two. Men standing at head and stern, with long poles of great lightness, guided and impelled them. The largest were built of teak wood, but the others consisted simply of a very narrow framework of rushes covered with bitumens, resembling probably 'the vessels of bulrushes' mentioned by Isaiah. They skimmed over the surface with great rapidity . . . .

"The tirada in which I sat was skilfully managed by two Arabs with long bamboo poles. It skimmed rapidly over the small lake and then turned into a broad street cut through green reeds, rising 14 or 15 feet on both sides of us. The current where the vegetation had thus been cleared away, ran at the rate of about two miles an hour, and as we were going towards the Euphrates was against us. We passed the entrances to many lanes branching off to the right and to the left. From them came black boats filled with Arab women carrying the produce of their buffalo herds to the Souk or market. As we glided along we occasionally disturbed flocks of waterfowl, and large kingfishers of the most brilliant plumage seated on the bending rushes watching their prey. Herds of buffalo here and there struggled and splashed among the rushes, their unwieldy bodies completely concealed under water and their hideous heads just visible upon the surface. Occasionally a small plot of ground, scarcely an inch above the level of the marsh and itself half swamp, was covered with huts built of reeds, canes, and bright yellow mats. These were the dwellings of Affaij, and as we passed by troops of half-naked men, women, and children issued from them, and stood on the bank to gaze at the strangers." (*Discoveries in the Ruins of Ninevah and Babylon.* 1853. pp. 549, 551–553.)

Mr. Kennett Loftus, who visited the Affij Arabs in 1854, thus describes the same marsh and its occupants :—

"We had now reached the commencement of those immense marshes which extend almost uninterruptedly to the Persian Gulf, and which, as I have previously said, cause the country under their influence to be a complete *terra incognita*. The swamps occupied by the Affej Arabs stretch, during the low season, from the Euphrates on the west, into the very heart of the Jezireh, and in some places even join those of the Tigris. It is impossible to state their area; but it is calculated that they support a population of 3,000 families, who pay an annual tribute of 100,000 piastres (about 900*l.*) to the Pasha of Baghdad. Abdi Pasha, however, thinking they were able to bear a considerable increase of taxation, proposed to double the above sum for the following year. The Affej were in no small state of fermentation and alarm, complaining

bitterly of he treatment they had at various times received from the authorities of Baghdad. Nedjib Pasha had thrice blown their fragile towns about their ears with cannon. These consist entirely of reed huts, the reeds being tied in large bundles and neatly arched overhead. This primitive construction is covered externally with thick matting impervious to rain. The riches of the Affej are indicated by rows of huge reed cylindrical baskets, containing the grain upon which they subsist. Rice is produced in great abundance along the edges of the marsh; but the whole of their fields were, at the season of our visit, and for a third of the year, entirely under water. Communication is kept up as on the marshes of the Hindieh, by means of long, sharp, pointed terradas, constructed of teak, and measuring twelve or fourteen feet long, by a yard in width. The Affej tribe is divided into two nearly equal parts, governed by two brothers, Aggab and Shkyer, the former being the accredited head of the whole."—(*Chaldæa and Susiana*, pp. 91–92.)

Plague was first observed at the end of December 1873 in the village of Dagarra, and the corpses of those who died earliest from the disease were carried to Nedjef for burial. The disease extended to others of the Affij villages, and in April attacked Diwanieh. Afterwards it spread irregularly in the district on the west bank of the river, intervening between that town and Hillah on the north, and Kerbella and Nedjef on the west, overlapping in short the scene of the outbreak of 1867.

This outbreak was investigated for the Ottoman General Board of Health by Dr. Castaldi, and his report of the result of his investigation has been published by that Board.* Dr. Castaldi estimates the population of the infected district to have been 80,700, and the deaths from plague during the three months April, May, and June 1874 to have been 4,000. Of these deaths upwards of 2,000 took place in Dagarra and the surrounding villages of the Affij tribe, of which the population is estimated at 35,000. The following table is constructed from the data given by Dr. Castaldi:—

Towns and Districts.	Population.	Time of Prevalence.	Stated Deaths.	Remarks.
Dagarra, with Haffytch and the villages of this district.	35,000	Dec. 1873—June, 1874.	2,000	—
		1874.		
Diwanieh district -	6,000	13 April—9 June	194 / 600	Probably 1,200 deaths.
Hillah - -	20,000	13 May - -	5	—
Sultan Mansour and Djerbolá.	1,500	17 May—13 June	82	—
Hum-el-Bahrour -	1,500	- - - -	8	All imported cases among a body of police.
Tueritch - -	2,000	10 May - -	1	—
Nedjef - -	4,000	1 May - -	22	Deaths among Persians unknown.
Midhadieh - -	700	April—May - (18 days)	120	—
Kerbella - -	10,000	25 June -	3	—
		State total deaths -	3,035	
		Estimated deaths -	4,000	

* La Peste dans l'Irak-Arabi en 1873–74. Rapport du Dr. Castaldi, Dèlègue Sanitaire en Perse. Constantinople, 1875.

Discussing the distribution of the disease Dr. Castaldi especially draws ttention to the exemptions of Hum-el-Bahrour, Nedjef, and Kerbella, notwithstanding introduced infection, especially in the first-named place, nd the presumably favourable conditions existing in the two sacred ities for the maintenance and diffusion of infectious maladies. He also omments upon a peculiarity of the symptoms, particularly as observed t Dagarra (these in other respects not differing from the symptoms bserved in the outbreak of 1870–71 in Persian Kurdistan), namely, requent bloody vomit at the beginning of the disease, the cases thus ffected dying within 24 hours, before the development of buboes. Bloody vomit has been noted in the case of plague recorded by Mr. Colvill luring the outbreak of 1867. This sympton is not mentioned in the ccount of the outbreak in Persian Kurdistan, but it will be again noted n the outbreak of the year under consideration in the province of Bengazi, bout to be described.

1874.—Bengazi Province.

The outbreak of plague in the province of Bengazi, in 1874, was nvestigated by Dr. L. Arnaud, one of the physicians in the service of he Ottoman General Board of Health, and a detailed report of the results f his inquiry has been published by the Board.* The disease appears o have been limited solely to the nomadic Arabs frequenting at the time f its appearance and prevalence the Cyrenaic plateau. The existence of lague was first observed in April 1874, but Dr. Arnaud is of opinion hat cases had occurred several months before. The outbreak had been pre-eded by three years' privation arising from failure of crops in the successive ears consequent upon persisting drought. In the winter months of 1873–74 the famine had become so severe that persons might be seen unting for undigested grain in the dung voided by camels. The cold eason of 1873–74 and spring of 1874 had been unusually wet and had onverted some of the favourite camping grounds of the nomadic tribes, s in the valley of Merdj, into swamps, adding to the misery of the tarving population for the time being, but rendering secure the summer rops. Mr. F. Henderson, H.M. Vice-Consul at Bengazi, who had passed through Merdj in April, states that he found there "the greatest " misery, the wretched inhabitants subsisting principally on wild " artichokes, and the village was almost unapproachable owing to the " continuous rains having converted the plain on which the village is " situated into a vast marsh." He states also that the famine which had followed upon the long-continued drought had decimated the popula-lation of Bengazi and the Bedouns of the plain; and that it was no uncommon thing at this time to find in the morning three or four corpses in the streets of Bengazi of persons who had perished miserably over night.†

At the crisis of misery, as it were, plague appeared in a diffusive form, and spread from encampment to encampment and to certain of the villages and monasteries in the highlands, but not to the two towns of the littoral or apparently to the tribes in the low-lying plains. Dr. Arnaud was able to follow the movements of the disease in some detail noting its dissemination through the inter-communication of the occupants of various encampments, and showing a period of latency after exposure to infection in three cases of 5 days, in one case of 6 days, and generally a limit of 8 days.

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* Essai sur la Peste de Benghazi en 1874. Rapport du Dr. L. Arnaud. Constantinople, 1875.

† Letter to *The Times*, 19th August 1875.

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In this outbreak, as in that among the Affij Arabs previously described, bloody vomit and a blackish vomit are described among the early symptoms. Buboes and carbuncles were almost invariably observed; petechiæ generally; boils rarely. The fatal cases ran a rapid course of from two to four days.

The following is Dr. Arnaud's tabulated summary of this outbreak:—

Tribes and Localities.	Beginning and Duration of Disease.	Population.	Attacks.	Deaths.	Recoveries.	Free from Seizure
Orphas - -	5 April—1 month -	34	10	7	3	24
Ferig-el-Hassan -	7 April—4 months	62	55	22	33	7
Kefauta - -	17 May—1½ months	75	50	25	25	25
Environs of Kefauta	22 May—1 month -	57	39	17	22	18
Merdj - -	28 May—2 months -	310	270	100	170	40
Segha - -	1 June—1 month -	3	2	2	—	1
Toukra - -	3 June—2 months -	16	13	6	7	3
Aït-Zekri - -	12 June—2½ months	32	29	11	18	3
Aït-Brakta -	Do. do.	33	27	7	20	66
Aït-Ahmet-Kméil -	15 July—2 months -	38	31	11	20	7
Aït-Abides -	24 July—1½ months	74	7	0	7	7
		734	533	208	325	201

Dr. Laval, a French Army Surgeon, resident at Bengazi, and who had observed the plague there in 1858, visited Merdj at the request of the Governor of the province, early in the outbreak, in order to ascertain the actual character of the disease which had manifested itself in that place, and of which the nature was then doubtful. In the course of his investigation, which made it clear that the malady was true bubonic plague, he unfortunately contracted the malady and died after a very short illness.

1874.—The Assyr Country, Arabia.

The outbreak of plague in the Assyr country, North Yemen, Western Arabia, in 1874, was investigated by Dr. Pasqua, the Inspector of the Ottoman Health Department at Jedda. He started inland upon his mission, from the port of Confoda, early in September, travelling by way of the villages of Halli and Mikaiel. The following is a summary of the results of his inquiry, as given by Dr. E. D. Dickson in a letter dated 12th February 1875, addressed to Her Majesty's Ambassador, Constantinople, and which contained the substance of a report on the subject by Dr. Buez, the French Vice-Council at Jedda, communicated by the Ambassador for France at Constantinople to the Ottoman General Board of Health:—

"Constantinople, Feb. 12, 1875.

"Towards the end of July 1874 Dr. Pasqua, inspector of the Health Department at Jeddah, was informed by the Governor-General of the Hedjaz that a malady resembling the plague prevailed at 'Doga,' a village containing from 200 to 250 inhabitants, placed at the foot of the 'Assyr' mountains, one day's march S.E. of Leeth, and four days S. of Mecca.

"A little later, on inquiry, Dr. Pasqua found that it was not at Doga that the outbreak had occurred, but among the 'Beni Sheir,' a tribe inhabiting the table-land of the Assyr.

"As soon as this was ascertained measures were taken by the Governor to prevent the infected locality from communicating with the healthy, and a quarantine station was established at 'Bin-Omar,' about three hours distance from Mecca. All maritime arrivals from the coast of Yemen were put into five days' quarantine at Jeddah, and were subjected to a medical inspection before receiving pratique. Inquiries were, moreover, addressed to the Medical

Superintendent of the military hospital at Mikaiel, the garrison station of the district, for information regarding the malady; and in the beginning of September, Dr. Pasqua went to Confuda, and from thence proceeded into the interior, in order to visit the seat of the outbreak.

"Confuda the principal port of Yemen, and Halli, a village beyond it, as well as Mikaiel, were all perfectly healthy; and the 80 patients lodged in the military hospital there presented no symptom whatever of any contagious or epidemic disease.

"On leaving Mikaiel the land gradually rises as you advance towards the 'Sinan' mountains, whose summits attain a very considerable elevation, and it is on the slopes of these mountains that the Assyr population dwells.

"The Assyr country, properly so called, is therefore between Nejd, Hedjaz, and Yemen. It is a vast territory covered with mountains extending from the 17th to the 20th degree of N. latitude, bounded on the N. by the torrent of 'Tabalah,' on the N.E. by that of 'Bysheh,' and on the S.W. by the Red Sea. Its population is reckoned at 60,000, a warlike race, subdued for the first time by the Turks in 1870.

"The lowlands are called 'Tehama,' a name also applied by the Arabs to denote the sandy plains extending between the Red Sea and the mountains all the way from Akabah to Aden.

"That part of the Tehama traversed by Dr. Pasqua offers a poor aspect, and its villages are mean, consisting of mud huts. Even Halli and Mikaiel, the two most populous, present a wretched appearance. The hospital at Mikaiel, however, is well kept. The 'Beni Sheir' are part of a tribe of 800 to 1,000 souls, spread over the Assyr mountains in encampments distant 10 or 12 days S. from Mecca, six days S.E. from Confuda and Leeth, and only three days from Mikaiel.

"The outbreak commenced about the end of March 1874, and continued in a *sporadic* form until the middle of July, when it became violent, and raged epidemically during the remainder of that month and the month of August, and assumed a decidedly contagious and spreading character.

"Such of the natives as had seen the *Plague* of 1853, which had committed great havoc in Arabia,* declared the present outbreak to be the same disease. The first locality attacked was the village of 'Ali-Saadi,' inhabited by 325 persons, of whom 100 perished within six weeks, viz., 40 men, 25 women, 15 boys, and 20 girls. The next village visited by the malady was that of 'Ali-Dogmain,' composed of 500 souls, of whom 50 died, viz., 10 men, 12 women, 20 boys, and eight girls. At the same time the village of 'Dogmain.' of 715 inhabitants, was attacked, giving a death-rate of 30, viz., eight men, six women, 12 boys, and four girls. Then followed the village of 'Ali-Marabi,' containing 210 persons, which gave 40 deaths, viz. 12 men, eight women, eight boys, and 12 girls, and so on.

"Most of these villages are situated on an elevated table-land called 'Toumouna,' rising about 2,000 metres above the sea and 1,500 above the 'Tehama,' and extending as far as the 'Namaz' range, from which it is separated by the valley of 'Waba.'

"Here a marked contrast is seen between the barren, wretched plain of Tehama and the fertile, pleasing aspect of the Toumouna plateau. The villages just named are built of stone; the houses have several stories, are well-aired and properly distributed; and the soil is rich, and produces the best quality of Yemen coffee, often giving two crops in the same year. Indian corn, dhurra, barley, and indigo are cultivated; vegetation thrives and fruit trees abound. Running water is scarce, but in lieu of it the inhabitants are supplied with wells and cisterns.

"The low country, on the other hand, is sterile and marshy, and has an elevated temperature. Dr. Pasqua's thermometer indicated there 36° (Reaumur?), while on the plateau it fell to 14°, and the air felt keen and chilly. Malaria fevers are absent in these elevated regions, and the prevailing complaints have a catarrhal tendency.

"The outbreak prevailed at first on the plateau of Toumouna, from whence

* Dr. Buez, in a paper on the subject published in the *Gazette Hebdomadaire de Médecine et de Chirurgie* (1875, p. 52) says, in reference to this point, "Pour les "habitants qui avaient observé cette maladie en 1816, puis en 1853, où elle avait "fait d'assez grands ravages, cétait la peste bubonique.'"

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it extended to that of Namaz, and even went beyond it as far as within four days' reach of Mecca. It then retraced its course and died out to the village of Namaz.

"When Dr. Pasqua visited Namaz on the 20th Sept. he only saw five cases of the malady, all more or less in a state of convalescence, yet as they were all marked with characteristic glandular swellings, he concluded it to have been the plague.

"The village of Namaz is composed of 46 houses, containing a population of 280 inhabitants, and a garrison of 135 zaptieh (police force). The Kaimakam (Lieutenant-Governor) of the district resides here, while the Mutessarif (Governor) of the Assyr lives at Mikaiel.

"On quitting Namaz Dr. Pasqua left there Dr. Agop Effendi, who had been detached from the hospital of Mikaiel for this purpose, and after returning to Jedda he was informed by the Vali (Governor-General) of Yemen, who had made a tour of inspection in the Assyr, that the outbreak had entirely ceased. This news was, moreover, confirmed by a report from Dr. Agop Effendi dated on the 22nd October, on the receipt of which by Dr. Pasqua the quarantine applied at Jeddah and Mecca on arrivals from Yemen was removed.

"The public health at Mecca was carefully watched all the while. No untoward event occurred there, either amongst the natives or amongst the pilgrims.

"On former occasions plague visited the Beni Sheir, viz., in 1816 and in 1853. In 1816 it was brought there by the Egyptian army, but to that of 1853 no origin has yet been assigned, and Dr. Pasqua believes that the late outbreak is due to a like cause, and he discards the idea of its importation from elsewhere, because the inhabitants of these elevated regions do not mingle with those of the lowlands, and, being Wahabbis, are thus excluded from intercourse with the true believers."

To this interesting account Dr. Dickson adds a remark made by Dr. Parznichi, in a report to the Central Health Department, dated from Djerzan, in Arabia, on the 18th December 1874, that "the localities "lately attacked by the outbreak of plague had been previously visited "by famine."

1875.—The Lower Euphrates.

On the 24th March 1875, Dr. Paduan telegraphed from Bagdad to the General Board of Health, Constantinople, that several fatal cases of plague had occurred at Diwanieh, on the Lower Euphrates, "since the "month of December." As already related, Diwanieh was within the district in which plague had been prevalent in the spring and summer of 1874, and the town had then suffered somewhat severely from the disease. On the 12th April, Dr. Paduan again telegraphed to the Board that two days before cases of plague had been seen by a military medical officer stationed at Samava, South of Diwanieh, while on a tour of inspection, in a place called Umulnidjrin; and also that the Mutessarif of Hillah had reported that the disease had spread to Shinafieh, on the eastern border of the Bahr-i-Nedjef. A cordon sanitaire had been place round the district of Samava, and the huts in which the cases had occurred at Umulnidjrin had been burned. Dr. Paduan added an expression of opinion that this appearance of plague was a continuation of the previous year's outbreak.

The cases of plague reported in the district of Samava and the appearance of the disease at Shinafieh were the commencement of an extension which spread over the districts, on both sides of the Euphrates, immediately south of those which had been affected in 1874. On the west bank of the river the malady spread throughout the district lying between the stream and the Sea of Nedjef; and on the east bank it spread throughout the district which lies in the angle formed by the Shat-el-Hai and the Euphrates, and along the whole course of the river Hai to the Tigris. This district is inhabited by the Montefik Arabs. The disease appears to have occupied a wider area in 1875 than in 1874, but the mortality it occasioned in the first-named year as compared with

the last-named year is not yet known. Immediately on the news of the appearance of plague in the Samava district reaching Constantinople, the General Board of Health there gave instructions for a medical commission to proceed from Bagdad to the infected district. The *ad interim* reports only of this commission have as yet been communicated to this Department. Surgeon-Major Colvill, attached to the British Residency at Bagdad, under instructions from H.M. Consul-General and Political Agent there, also visited the infected district. I append in a note so much of the report prepared by Mr. Colvill on the results of his visit as is necessary for the purpose of this memorandum. The report is of peculiar interest and value from the account it gives of the localities traversed on the Euphrates and the state of the river between Lamlum and Samava, and for the information it contains regarding the prevalent disease.

In December 1875 a few cases of a bubonic malady, presumably plague, were reported by the Sanitary Administration at Bagdad to have "occurred at Azizie, near It Hané," on the Euphrates.

At the beginning of the present year (1876) plague again became active in Mesopotamia. The re-appearance of the disease there was announced in the third week of February; but the disease had been present in that town on the 1st January, one death from it having been recorded on that day, and not less than 50 deaths from that date to the close of the month. A telegram from H.M. Representative at Constantinople to the Principal Secretary of State for Foreign Affairs, dated 17th March 1876, states "that plague is increasing in Mesopotamia "and that there have been five cases in Bagdad itself."

1876.

Note.

Report by Surgeon-Major Colvill to H.M. Consul-General and Political Agent, Bagdad, on Plague in Mesopotamia, 1874–75.

Mr. Colvill on Plague in Mesopotamia, 1874–75.

"Bagdad, June 5, 1875.—I have the honour to report my progress along the Euphrates in search of plague. In order to make myself understood it will be necessary to give some account, but so far only as my present object is concerned, of the line of country travelled (for it is practically unknown to us), and if possible to append a rude plan, for all the maps I have seen are not only deficient, but misleading; towns are marked in large characters which have now no existence, while other towns have risen which have no place on the map; large canals with extensive permanent lakes which have existed of old are a blank, and the Euphrates is traced on these maps as a large river to its junction with the Tigris, while it actually disappears between Diwaniyah and Samawah.*

"In this description of the country I will divide my route into sections from one central town to another, the first being from Bagdad to Hillah. With reference to the subject under consideration one point only in this section requires notice, and it is this, that at Musseyib, 30 miles in a straight line above Hillah, a canal leaves the right bank and carries off half the water of the Euphrates. This canal is called the Hindeah, and passes through a district having Kerbella to the west and Hillah, with the ruins of Babylon, to the east, and at Meshed-Ali (Nejef) it opens into an inland sea, 60 miles long by 30 broad, called the Bahr-il-Nejef. It was in the marshes to the west of this Hindeah canal that the plague appeared in 1867. The water in the Sea of Nejef becomes brackish, and issues by a canal or river called the Shat-il-Shinafeah, which, after taking a southerly direction for about 20 miles,

* I have substituted for Mr. Colvill's rough map, a map based on actual survey.—J. N. R.

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branches into two, the southern branch, the one used for navigation, being called the Atshan, while the other one is called Aber-Rufoosh, and both open into the Euphrates a little above Samawah. On the right bank of the Shat-il-Shinafeah, and within sight of the dome of Meshed Ali, stood the village of Shinafeah, to be afterwards mentioned. Most of the Mahomedan pilgrims from India to Kerbella and Nejef follow up the Euphrates, the Atshan, and the Shat-il-Shinafeah, and I saw vessels of 50 tons passing.

"My second section is from Hillah to Diwaniyah. During the first two-thirds of the way by river a number of canals, varying from seven to ten yards in width, open from both banks, and end in separate small marshes. Those opening from the left bank, in the order from Hillah, are: 1, Wurdieah; 2, Rumeah; 3, Abu Hassan; 4, Fanarah; 5, Be Rumanah; 6, Lanadal; 7, Shomlie; and, 8, Abu Chumach. Those from the right bank, in the same order, are:—1, Michereah; 2, Homaneah; 3, Alach; and, 4, Jerbocah. All these canals are farmed from Government by merchants in Hillah, and the cultivators reside permanently in Hillah, and live only by the canals in tents or reed huts while they grow the wheat and barley. No more canals open from the right bank of the river, but one-third from Diwaniyah, and therefore two-thirds from Hillah, on the left bank, is the opening of the Dagarah canal. This canal is 60 to 80 yards wide, and of considerable depth, and runs almost due east for 12 miles to the foot or enclosure of Dagarah. Its banks are some feet higher than those of the Euphrates, and there are numerous cultivators on both sides, who have to raise the water for irrigation in skin buckets drawn by horses or oxen. Their habitations being close to the canal are therefore on dry ground. At the fort of Dagarah the canal divides into three or four, but these quickly give off branches which run over ground lower than the surface of the water. This ground is used for the cultivation of wheat, barley, or rice, and the cultivators, who are all permanently settled, occupy reed huts built on ground saturated with moisture. Eight miles more and these waters again collect into a reed-bearing marsh, 22 miles long and 10 broad, but with a large space of open water in the centre. At the eastern end this marsh forms minute canals, which quickly join, becoming larger and fewer till at the village of Afiche they form one large canal, called the river Micherie. This is the district of Afiche. As at Dagarah, its ground is lower than the surface of the water, and its inhabitants permanently dwell in huts built on ground saturated with moisture. Twelve miles along the river Micheri is the village and small district of Abdare, exactly of the same nature as regards cultivation, irrigation, and habitation as Dagarah or Afiche. And now the canal takes the name of the river Karr, and bends round, as may be seen on an ordinary map, and opens into the Euphrates a little above the opening of the Shat-il-Subil (Shat-il-Hai). These canals closely resemble the arterial system; the Dagarah canal bearing the muddy water of the Euphrates represents the artery dividing and subdividing, while the marsh is the capillaries, for here all the mud is deposited, the water becomes perfectly clear, but acquires a deep black tint from the carbon of decayed vegetation and a strong marshy flavour; the river Micheri, which carries off the water, is of course the vein. A process something of this nature also happens in the Sea of Nejef, and it will be seen that almost all the solid particles of the whole of the waters of the Euphrates are precipitated before that river joins the Tigris, but what it gains in clearness it loses in flavour and quality. Six miles above Diwaniyah, at a place called Abu Fadal, another canal, 30 yards wide, opens from the left bank of the Euphrates, and runs in a south-easterly direction through the intermediate ground between the river Karr and the Euphrates. After a course of about 30 miles it opens into a marsh, and here is the village of Fowar, with its surrounding marsh district. As to cultivation, irrigation, and habitation, Fowar is the same as Dagarah or Afiche. The water of this canal is nearly all absorbed by marsh and cultivation, but a small stream from the marsh opens into the Euphrates between Samawah and Al-Khudhr. The town of Diwaniyah, built almost entirely of sun-dried bricks, is situated on both sides of the river which is crossed by a bridge of boats. The population is about 2,500, consisting, besides the government officials, chiefly of shopkeepers for the supply of the surrounding villages, and of agents for the purchase of wool and grain. There are besides two regiments of infantry, a battery of artillery, and usually a regiment of cavalry, said to be necessary in order to collect the revenue.

My third section is from Diwaniyah to Samawah. From Diwaniyah, halfway to Samawah, the country is without a tree, without cultivation, without a canal leading off, save one, and that very small, in the direction of Fowar, with no brushwood thicker than the finger or more than 2½ feet high, and not an inhabitant, save a few tents, 200 in all, of black hair of the Garoul. These are Bedowins who wander about on both sides of the river, and though they will not condescend to till the ground, they carry the grain from the country to town on their numerous camels. At this half-way, however, two miles inland from the right bank, is the solitary tomb of Humza, a son of Kauthem. Not a soul lives near it, but there are four guardians appointed, who take it week about to watch the tomb. A little further on, however, on the left bank, is the village of Humza. This is quite a recent place, consisting of 80 houses on dry ground, and from this cultivation begins, but the bank being high irrigation has to be performed in skin buckets drawn by horses. Surah, Antakiah, and Lamlum, towns marked on the map, have ceased to exist. There were two Lamlums, one, on the right bank, said to contain 10,000 inhabitants; probably true, for the ruins are extensive, but it was destroyed 44 years ago by the plague. The remaining inhabitants fled to the left bank and founded the second Lamlum, which, 15 years after, was also deserted as the river altered its course. These people then divided, the smaller portion forming a village on the left bank called Um-Nejeris, within sight of Jawariyah, marked on the map, while the majority founded the town of Rumoetha, nearer to Samawah, and also on the left bank. Before reaching Um-Nejeris the banks became low, and the water, when I was there, was pouring, as it does all the spring, over rice fields as far as one could see, and Um-Nejeris itself is a village of exactly the same stamp as Fowar or Afiche.

Jawariyah, however, is different, being built on a strip of dry land comparatively high. Rumoetha is a small but well-built town, with a good bazaar, and 300 houses, on a dry situation, comparatively high, and it is surrounded by gardens, which show that the subsoil around is not so damp as to rot the roots of trees. From Rumoetha to Samawah it is nothing but rice fields and marsh, with many little villages of reed huts on the drier ground. But be it remembered that all these villages are shifted twice a year, for so soon as the water falls the huts are all carried to the rice fields, and there remain till next spring rise, which completely washes and cleans the ground occupied by these villages during the greater part of the year. So great is the drain for the rice fields, that 20 miles below Rumoetha, at a place called Abu Chelib, the demand for water is greater than the river Euphrates can supply, and a back current sets in with force, this being the brackish water from the sea of Nejef, through the Shat-il-Shinafeah and the Aber Rufoosh. So that, in fact, the great river Euphrates is lost in the rice fields at Abu Chelib. The Aber Rufoosh and Atshan having joined a large river with comparatively high banks leads to Samawah. Samawah is a town of 3,500 inhabitants, built on both sides of the river; it is, in fact, a duplicate of Diwaniyah, with this exception, that there are a number of gardens about it, and only 300 infantry and two guns.

My fourth and last section is from Samawah to Sook-il-Shiook, close to where the Shat-il-Hai opens into the Euphrates, and on the same side is the new town of Nassreah, founded five years by Nassr Pasha, chief of the great Montefik tribe, in order to perpetuate his name. For half the way from Samawah to Nassreah the banks of the river are comparatively high, and irrigation has to be carried on by skin buckets, the inhabitants remaining on the ground only during the growing season, and for the rest of the year living in Samawah and Al Khudhr.

Al Khudhr is a mud-built village of 200 houses, high and dry on the left bank. It surrounds the tomb of Khudhr, a son of Kathem. For the other half of the way to Nassreah, the country on the left bank is a swamp partly from the Euphrates and partly from the Shat-il-Hai. On the right bank it is a desert, and the only building to be seen is a domed room, built for the prophet Jonah, who is supposed to visit this earth two or three days every year, and having been once seen here it is supposed he may return, and the room is built for his reception. Within sight of this room I was caught in a storm. It had been calm all day, but towards evening a speck appeared in the north-west, which increased alarmingly fast. Clouds of dust rolled over clouds, and as they passed to the left took the form of ranges of hills with very bold fronts chasing one another.

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The boatmen, alarmed, ran their canoe into a niche in the bank; the sun disappeared; still scarcely a breath of wind. Presently there was a noise like the sea; not a roar, but the rattle of waves on the beach, and the storm came in earnest. It quickly passed, and settled into a squally night. It was probably a gust of this kind which swamped the steamer "Tigris" in Colonel Chesney's time. The town of Nassreah, of about 3,000 inhabitants, was planned by a Belgian architect. The streets are wide and parallel, or at right angles; all the houses are of mud, except the barracks, containing also the Government officers and the house of the chief. The Shat-el-Hai is a canal of the olden time, but it differs from all the other old canals that led from the Euphrates to the Tigris in so far that its openings at the Tigris and at the Euphrates are on the same level, so much so that the current in the canal is changed with any sudden rise of either of the rivers. The Shat-il-Hai, opening from the Tigris at Kut-il-Amarah, retains its name from the first third of its way, but during the middle third it divides into two, the easterly branch being called the Shat-il-Amah, and the westerly Abu Jeheirat. These two again join, and for the last third the canal is called Shat-il-Subī. Hai Wāsut, with the district round, contains 4,000 souls, and is situated on the Shat-il-Hai, 25 miles from Kut-il-Amarah. It is built partly of mud, and partly reed matting. Jelat Sekker, a village with its district, contains 2,000 inhabitants, and is situated on the Abu Jeheirat. The village of Shatra, with its district, contains 6,000 souls, and is situated on the Shat-il-Subīl. These three villages, partly of mud and partly of reed matting, are of the same class as regards position, cultivation, irrigation, and habitation as Um-Nejeris and Fowar. Three years ago Nassr Pasha attempted making an embankment along the right bank of the Euphrates from Nassreah to Busreh, in order to prevent the country to the south being flooded; the idea was grand, but no one having the slightest notion of the force of water, with the first rise of the river the embankment disappeared, and the Arabs who were forced to work at it fled to the Shat-il-Hai, and placed themselves under the mild rule of Fahad Pasha, brother of Nassr. This is worth noting, for if plague attacks them on the Hai, they may return to their old haunts. Sook-il-Shiook, or the bazaar of the chiefs, contains 2,000 inhabitants, and is a dirty, tumble-down place of sun-dried bricks. Its chief feature is a long bazaar, which contains nothing unless the daily wants of a poor people. Sook-il-Shiook is said to be falling into decay since Nassreah was built, and so dirty is it that the sooner it becomes a thing of the past the better for its inhabitants. It is about 16 or 20 hours by boat from Busreh.

Having finished the outline of my route, so far as it has reference to the subject of this letter, I shall now sketch the progress of plague. In the spring of 1874, plague appeared amongst groups of huts in Dagarah and Afiche, and it was imported from there into Diwaniyah, where 400, including the Governor's son, out of a population of 2,500, died. At the same time it appeared in Shinafeah, but whether spontaneously or by importation I cannot say. Last spring a man arrived from Afiche at Um Nejeris, and died in a hut of plague; and two to three days after his arrival, the first case of plague occurred. Four people in that hut died, all who fell ill, leaving two only untouched. In all, 20 people in a population of 500 died, and some 20 recovered. The heats having set in, the disease became dormant till last autumn, when it again appeared at Um Nejeris, and four persons died, but the greater number recovered. Plague again became dormant till the beginning of January of this year, when it was reported to exist on the Shat-il-Hai. In the beginning of February it was carried to the district of Abdare by some Montefik Arabs from the Hai, and about 150 in the district died, out of a population of 4,000 souls. The disease did not enter the village, which consists of 50 houses. About the beginning of March the disease appeared in the village of Fowar, in the heart of the bazaar, but how it was brought there I could not find out, as the first cases were concealed, and a number of deaths had even taken place before the authorities were aware of the existence of disease; and it was not till the 9th of April, when a southerly wind set in, and 40 people were seized on a Friday and Saturday, and almost all died, that the existence of disease was declared. From that time the epidemic there decreased; and when I visited the place on the 8th of May, all the cases I saw were in reed huts on the outskirts of the mud

bazaar. The village of Fowar had a population of about 250 souls, and up to the time of my visit 43 were known to have died, though there were probably more deaths. On the 16th of April a man arrived from Fowar, and spent the night in a garden-house on the outskirts of the town of Diwaniyah, on the left bank of the Euphrates. He fell ill of plague, and died there. After a few days, exact time unknown, four of the gardener's family died, besides a little daughter, who was carried by the father in a dying state to a garden-house on the opposite bank of a river, and left there. He returned next night, and took his child, who meanwhile died, back with him. Forty-eight hours after taking the girl to the gardener's huts on the right bank of the river, the first of this man's family was seized; there were here 15 people in all, divided into four huts: in one hut, father, mother, and son died, all it contained; in another hut, a woman living by herself died; in a third hut, two girls died, leaving father and mother and one girl behind. One or two Jews went to this garden on the 28th of April, and four days after, a boy, fifteen years of age, was attacked; but when I saw him on the 7th of May, he was recovering, with a bubo on the left groin, which had burst. A soldier from the barracks close by was also attacked, after entering this garden, but was recovering when I saw him. Another soldier from the barracks, after visiting a village three hours distant, towards Shinafeah, where he entered a hut, of which, to use a local expression, the doors were shut, meaning that all had died inside, returned to Diwiniyah, and died. At Shinafeah, which has a population of about 1,000 souls, 108 people died this spring, up to the beginning of May, when three-fourths of the villagers fled into the marshes, probably alarmed by 24 people dying within three days. At Um Nejeris, up to the date of my visit on the 11th of May, 60 people had been seized, out of which 40 died, and the disease still existed in the village; though from an evident dislike to my visiting the patients, the heads of the people declared that women only were attacked, and trusted I would not insist on seeing them. As I mentioned, plague appeared on the Shat-il-Hai in the beginning of January, and it then attacked the village of Jelat-Sikker, containing about 2,000 inhabitants, and after about from 460 to 470 had died, the villagers fled, not leaving twenty-five people in the place, and a few went to Kut-il-Amarah on the Tigris, where one or two of them died, thus creating alarm. At Hai Wasut, containing about 4,000 souls, up to the beginning of May 500 people had died; and when I was in the neighbourhood the disease still existed. At Shatra, the disease appeared only about the middle of April, and was increasing in the beginning of May. From Shatra, plague was carried into Nassreah by two messengers on the 20th of April. One of the messengers died, and the other returned to Shatra. Between two and three days after the entrance of the messenger into a house in Nassreah, where he stayed, the head of that house was taken ill. Altogether, up to the middle of May, about thirty people died. At Sook-il-Shiook, the plague appeared about the middle of March, and 200 people died out of a population of 2,000, but no deaths had occurred since the beginning of May.

A triangle, with one angle at Kut-il-Amarah on the Tigris, another at Shinafeah, and a third at Sook-il-Shiook, will include the infected district, which, it will be seen, has greatly increased since last spring. It is almost impossible to give an idea of the total number of deaths in the whole district, because the natives are so given to exaggeration. But if it is supposed that half of the villages within this triangle were attacked, that the number of deaths was 13 per cent. of the inhabitants of the infected villages, and that the whole population is 12 to a square mile, this will give a little over 4,000 deaths for the two years, and I suppose it is pretty near the truth.

The symptoms of this disease are fever from twenty-four to thirty hours, but often immediately before that the patient appears more than absent, rushes along the bazaar, speaking to no one, enters his house mechanically, shutting the door, and drops on to his bed as if in despair or wandering in his mind. When fever sets in, the patient becomes stupid, his eyes are red and turbid, and he looks like a drunken man, or he is delirious, and on being asked a question, only answers with a moan. His tongue is swollen, generally blackish brown, and fissured, sometimes white or yellow. There are invariable sordes about the teeth and gums; the thirst is intense, and in certain cases, if the patient is able to answer, he complains of pain in the epigastrium, as if

being stabbed by a knife. In this epidemic there is very little vomiting, though, in certain cases, the patient vomited blood towards the end. The breathing is hurried, and the pulse during the fever stage is very rapid. The urine, as a rule, is natural, often pale and abundant, but as the case goes on, he often passes blood from the bladder. There is almost always obstinate constipation, and when diarrhœa appeared, it was looked upon as a good sign. When the fever left, the patient burst into a profuse perspiration, and became sensible, though very weak. With the fever, or oftener a few hours after it had set in, there was intense pain in the groin, armpit, or neck, and so sudden was the swelling of the lymphatic glands that the attendant often discovered a considerable enlargement on the first complaint of pain, and no case occurred in which the swelling of the glands was absent. The glands in the groin more frequently swelled than anywhere else, next to that in the armpit, the glands of the neck swelliing more rarely than any. The glands of one groin as a rule swelled, but sometimes in both groins, and indeed anywhere, it was seldom one gland only, but a chain of half-a-dozen, one being larger than the others, round, the size of a walnut, or oval, the size of a pigeon's egg. Petechiæ occurred only in fatal cases, and then only two or three hours before death. Carbuncles did not occur this year, but appeared in Diwaniyah last spring in a certain number of patients, and were looked upon as a good sign. Death occurred from two to seven days, and if the patient survived to the twelfth day, he was considered to have escaped. The mortality in the first half of the epidemic in a village was from 93 to 95 per cent. of those attacked, but during the latter half the greater number of patients recovered; and it is to be remarked, that though plague may be decreasing, and most of the patients be recovering, when the disease is transferred to another village, still that other village fares no better, as if, from some predisposing cause, a certain number of victims are marked out for destruction, while the decrease is due, not to a diminution in the vitality of the disease, but probably to the fact that all those most liable are killed among the first. It was constantly remarked that many more people fell ill during a southerly wind than when the wind was in the north, and this is an observation that was made 102 years ago, when the plague attacked Busreh. I always lay considerable stress on the opinion of intelligent people who saw the plague in 1831-32, and all agree that this was the same disease, with the exception of two men at Fowar. These two men said it was like it, but different because the carbuncles appeared, and one pulled off his shirt and showed me a large scar on his back, which had discharged matter for months after he had recovered. Again, said they, the patients then became as drunk, never recovering; while now, when the fever leaves them, they declare themselves well, often smoke, but still they die. We, however, know that carbuncles are not necessary in order to establish plague. There is one point, and before I entered those districts I was misled by it, and it is this—if this is plague, why does it spread so slowly? and it does require a visit to understand it. In the early spring, when the cultivators are ploughing and completely occupied, there is no intercommunication between one village and another, and no visits are paid from the towns, because there is no revenue to collect; and when the revenue-men do spread abroad and the villagers have less to do, the season of plague has almost ended: for I consider that between the end of May and the 10th of June it ceases, or, I should rather say, becomes dormant. In 1831, when plague ceased in Bagdad, it lingered during the summer and winter on the Shat-il-Hai, and in 1832 attacked Busreh, while but few people suffered in Bagdad that year. Here we find it last spring attacking Um Nejeris, lying dormant during the summer, appearing slightly in autumn, becoming dormant again during the severest winter that has been known in this province, and again appearing this spring. Diwaniyah, it will be noticed, suffered severely last spring, and though plague was brought to its door this spring, yet it escaped. That this is plague there cannot be the slightest doubt, but still it is a plague not properly developed; whether it will arrive at maturity next year, demands considerably thought, because Bagdad, Hillah, Kerbellah, Nejef, and Busreh, lie round the infected triangle; and if this is plague in a state of incubation, be it remembered that it will be hatched much farther east than before, for all former plagues came from Egypt or Syria.

I have already, besides mentioning the towns, described four classes of

villages or groups of huts. One class where irrigation takes place with skin buckets on account of the high bank, and the huts are on dry ground and therefore receive all the antiseptic influence of earth. In the second class the villagers only spend the season of cultivation on the ground and return to the towns for the rest of the year. In the third class the villagers are driven, on account of the rise of the water from their rice-fields, and forced to move their habitations twice a-year, while the ground they occupy during the greater part of the year is thoroughly cleansed by the rising river. Those three classes of villages are all free from plague, and the disease is confined to the fourth class only. In this class the villages or groups of huts are permanent; they are on ground which is a foot or two lower than the surface of the water in spring, and the ground is so saturated with water that the refuse of the village is neither absorbed nor can it be evaporated, for it acquires fresh moisture from the ground, and this refuse acquires the form of a bluish-black oily fluid, which surrounds the huts and covers the paths, and stains the walls two feet from the ground; and, in fact, the village is in such a state of filth that it requires to be seen to be believed. It was this class of village which was exclusively attacked in the Hindeah in 1867. It is no exaggeration to say that every hut in this class of village is a filthy pigsty; for put the pig in in the morning, and in the afternoon he will be wallowing in the mire, so moist and polluted is the ground. It may be remembered that the towns of Diwaniyah, Nassreah, and Sook-il-Shiook have been attacked by plague, but the disease was imported, not hatched there. . . . . .

I can see no reason why it should have attacked this district last spring, and this in preference to any other year; for during the past two years every kind of grain has been in profusion, dates in abundance, and fish on the Euphrates are caught simply for the sake of the oil. It may be remarked that, during last spring, there was an excess of rain as in 1867, but that could not affect villages moist as these are. Still, it is a significant fact that the only two great inundations of the rivers since 1831 occurred in 1867 and last spring, and that during the great plague of 1831 there was an inundation of the Tigris which washed half Bagdad away. In 1867, however, the disease died away in one spring, while this year the area has much increased since last year.

. . . . I cannot conclude this Report without mentioning the exceeding kindness I received from all classes and creeds along the entire route. I seldom entered a village where I was unknown, and some one at least did not thank me for professional assistance rendered him or his relations. In fact, high and low were most anxious to serve me.

Fowar.

May 8.

Case I.—Hassan ibn Abood, 25 years old.—His mother died yesterday, and n the afternoon, returning from the funeral, he was seized with fever, unable to walk, had to be put on a donkey, and was not brought home till midnight. Though intelligent in health, the patient appeared semi-comatose, very restless, and moaning, sometimes crying "Mother, mother," and he requires to be spoken to six or a dozen times before he can understand the simplest question. Lifted to a sitting position, the head rolled from side to side. He complains of pain in the groin. Drinks much water. There is no vomiting. The glands began swelling only within the last two hours, and now a chain of glands are swelling in the right groin. His tongue is white, furred, and swollen. He seems as if drunk. There are sordes about the gums and teeth. The breathing is 40 and laboured. Pulse 130; no petechiæ. Constipation. No headache. Passes water pale and natural. Eyes bloodshot and turbid. No perspiration, and the skin is hot. The mother and son were the only inmates of one hut.

Case II.—Mahommed ibn Mustapha, 50 years of age.—He is a coffee man by trade, and desired to open his shop the day before yesterday in the morning, but returned with fever, which has just left him, and he now perspires freely. Yesterday he felt the chain of glands enlarging in his left groin, and to-day they have increased, the largest being the size of a walnut. There is intense

pain, and great headache. Tongue furred, swollen, and very white; sordes about the teeth and gums. Bowels constipated. Urine scanty and high coloured. Pulse 95. Breathing 36 laboured. Eyes clear. Patient is now very weak, but sensible. Yesterday, however, he is described like one drunk. He drinks much water. No petechiæ. Has a wife and child, but no one has previously died in his hut.

Case III.—Hajee Sultan, 35 years of age.—Four days ago returned from his shop in the afternoon with slight fever, which increased in intensity, and only left him to-day. With the attack of fever the gland in the right groin swelled. Till to-day he has been delirious. He now perspires. The glands in the groin pain intensely, but not now. The tongue is black, dry, and swollen, and cracked. There is intense thirst, and sordes about the teeth. The bowels are freely opened; in fact, he has diarrhœa, and the excrement is very offensive. The breathing is 60, but not laboured, and the pulse 96. He passes much dark urine. His eyes are heavy looking, but neither bloodshot or yellow. No petechiæ. Patient very weak. He has had no vomiting.

Case IV.—Abid, a boy 4 years old.—Yesterday afternoon had fever, and this morning a mass of glands swelled in the left axilla. He only cries out "Head, head," answers no questions, and appears to understand nothing, being quite stupid, and tossing about, and he also appears frightened. Tongue, so far as can be seen, is white and swollen. The eyes are yellow and heavy. The breathing 52 laboured. Skin very hot. Pulse 150. Last night he vomited a white froth every hour, but this has ceased. The bowels are constipated. There was no urine yesterday, but to-day once scanty and dark. There are sordes about the gums and teeth. No petechiæ. He only moans, and drinks much water.

Nassreah.

Temperature of the air in the shade, 93° at the time of these visits.

Case I.—Jassim ibn Moolood, 30 years of age, and a butcher by trade.—This morning at 2 o'clock he returned home like a child without sense, mechanically shut his door and dropped on his bed, complaining of pain in the left groin. Tongue is red at the margins, white in the centre, and dry. Pulse 132, very feeble. Breathing 24. The temperature of the skin in the arm-pit, 94°. He complains of intense pain in the groin, though the glands are but very slightly enlarged, but evidently swelling. Bowels are constipated. He passed this morning about a pint of urine, with blood. The eyes are yellow, heavy, and dull. There are no petechiæ. On complaining of pain in his groin, 1½ lbs. of blood was taken from him; and, though it is said that at the moment the heat of skin left him, still he did not perspire. He answers questions with great difficulty. He is quite prostrated, and evidently at the point of death.

Case II.—Rima bint Atti, 45 years of age.—Three days ago at night she had fever, but before the fever came the glands enlarged in both groins. At present there is one gland in the left groin the size of a small orange, and the chain gradually diminishes in size. In the right groin the gland is oblong, but not so big as in the left. The swelling appeared in the left groin after it appeared in the right. Pulse 140, weak. Breathing 40, but appearently easy. Temperature of the skin in the breast 100°. Tongue red and fissured. Sordes about the teeth and gums. No headache, but moans from pain in the groins. Bowels constipated. Passed blood yesterday, twice with urine, which is natural in quantity, vomited bile yesterday, but none to-day, though she complains of bitter taste in her mouth. She answers questions readily, but when raised complains of giddiness in the head, as if a knife was stabbing her in the epigastrium. The eyes are yellow and heavy. No petecchiæ. She perspires freely, and does not drink much water.

Case III.—Zafaran, a female negro slave of an officer, 18 years old.—Yesterday at seven in the morning she said she could not work, and immediately the glands in the right groin swelled. She spoke once or twice yesterday, but not since. Pulse 147. Breathing 42, laboured. The temperature of the skin in the arm-pit 96°. On being spoken to, she only answers with a moan. Mouth

half open, tongue slightly protruding. There are sordes about the gums and teeth. The bowels are constipated. She passes urine involuntarily. Last night it was yellow, but to-day it is red, as if mixed with blood. She is too comatose to open her eyes or show her tongue.

Case IV.—Salaman ibn Jaffer yesterday afternoon was seized with headache and fever. There is no enlargement of the glands. The tongue is furred, white in the middle, and red round the margins. Urine yesterday pale and abundant. Pulse 120. Breathing 36 easy. Temperature of the skin in the arm-pit 99°. He perspired freely all night, and this morning complained of a sharp pain in the epigastrium. The eyes are white and clear. He drinks much water, but cannot taste it in his mouth. He answers questions quite readily, and in fact it does not appear a case of plague, though the attendants say it is.

I was on my way to see another patient, when I was told that he had just died, after three days' illness, and unfortunately was carried to the grave before I got there.

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PUBLIC HEALTH

REPORTS

OF

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REPORT.

TO THE LORDS OF HER MAJESTY'S MOST HONORABLE PRIVY COUNCIL.

Iy Lords,

Medical Officer's Report

In accordance with the desire which your Lordships, on my tirement from office, did me the honour of expressing to me, at, when the various reports which were yet to accrue from the Iedico-Scientific Investigations of last financial year should be mplete, I (though no longer in office) should fulfil the agreeable ity of seeing to their passage through the press, I submit the resent volume to your Lordships; and as the date of my doing is is by some months later than I had hoped it would be, I beg ave to state that the completion of the printing has been delayed y circumstances not in my control.

1. The first report which the volume contains is a further con-ibution by Dr. Sanderson to the study of the Morbific Ferments. It relates particularly to the common ferment of putrid infusions, -a ferment which, besides having power to excite putrefaction in ead animal matter, has (as former of these reports have shown) ery definite toxical relations to the living animal body. Dr. anderson now shows that, if infusions which have the septic rment in them be passed under pressure through porous porce-in, the filtrate (which after such filtration has no microphytic rganisms in it) will now not undergo any further zymotic process itself, and, if introduced into the living body, will not exercise ny morbific influence on it. These results have at least an impor-nt negative bearing: for, had contrary results been obtained, nd had the septic liquid been shown to contain its characteristic rment in the mechanically-inseparable state of true solution, is fact would have conflicted with our opinion, previously xpressed, that the morbific ferments are essentially particulate, nd probably have their essence, or part of their essence, in the ultiplying organic forms (microzymes) which they contain.*

* As regards the component parts of the previous opinion, it will be observed at Dr. Sanderson in the present paper, though apparently still supposing that e septic ferment is particulate, seems to regard as proven by Professor Panum's periments, as well as approximately by his own, that it "does not consist of living ganisms." I think it better not to attempt on the present occasion to follow any the lines of consideration which suggest themselves with regard to that distinction.

MEDICAL OFFICER'S REPORT.

But while the verdict is to that extent distinctly in favour of the previous opinion, the test cannot, I apprehend, be considered unambiguous for purposes of positive argument, till we know for certain that the filtration-process, which obviously does arrest all visible particles, does not at the same time effect any other change which can be deemed essential in the liquid which goes through the filter.

This report from Dr. Sanderson represents all that his other engagements would allow him to do in the way of scientific investigations under your Lordships during the year 1875–6; and I much regret to have to state that, at the time when my own official connexion with the Department was ending, Dr. Sanderson had found himself unable to accept any commisssion under your Lordships for the year which is now drawing to its close.

2. The next three papers in the volume are by Dr. Klein. The first of them (App. No. 2) is a short memorandum in which he refers to his previous report on Sheep-Pox, and rectifies a very important error of interpretation in that report. It had chanced that Dr. Creighton, while studying preparations which he had made of glandular textures for the purpose of his own researches in Cancer, came on appearances so similar to some of those branching forms which had been found by Dr. Klein in the skin-eruption and skin-lymphatics of variolous sheep, but at the same time so certainly due to his own method of anatomical preparation, that he was led to believe that Dr. Klein's interpretation of the sheep-pox appearances had been in part erroneous; and upon his doing me the favour of drawing my attention to the supposed fallacy, which I at once brought to Dr. Klein's notice, Dr. Klein returned to his examination of the variolous specimens, and eventually came fully to recognise that Dr. Creighton's contention was just. The effect of the above correction is to set aside as mistaken those parts of Dr. Klein's paper which represent the higher fungic structures, mycelium and gonidia, as existing in variolous skin; and on consideration of all the circumstances, I am disposed to think that provisionally we ought to regard this correction as applying also to certain parts of Dr. Klein's paper on enteric fever, and as invalidating, till further examination shall have been made, the descriptions which he there gives of higher fungic forms in the follicles of the diseased intestines. Dr. Klein is confidently of opinion that the correction does not in either case affect those parts of his description which represent the diseased textures as pervaded by swarms of micrococci; and this is also the opinion of Dr. Sanderson, under whose superintendence the former researches were made; but as it will, I think, clearly be convenient that Dr. Klein should at the earliest opportunity re-write, under the present correction, his account of the morbid anatomy of the two diseases, I would suggest that, in preparing to do this, he should re-examine, so far as any doubt could be raised, the whole ground of the former investigations.

As regards the curiously fallacious microscopical forms by which Dr. Klein was misled, I think it due to him to state that not only did those forms lead other skilled animal-histologists who saw them to concur with him in believing them to be extrinsic organisms, but that also botanists of the highest European authority accepted them without demur as truly fungic.

3. Dr. Klein's next paper (App. No. 3) gives the results of an elaborate investigation he has made of the intimate anatomical changes which arise in various organs of the body during the progress of severe Scarlatina.

His results, so far as the investigations have gone, do not seem to me to justify any final opinion with respect to the nature of the scarlatinal contagium; but the detailed illustrations which he gives of the peculiar working of the infection in a great variety of organs seem to me a very interesting addition to previous knowledge, both as regards the scarlatinal infection in particular, and as regards febrile infections in general. In these points of view I would especially draw attention to the evidence which Dr. Klein seems to find that scarlatina tends to produce widely-diffused textural changes in the walls of bloodvessels,—a hyaline swelling of the texture of capillary vessels and of the inner layer of minute arteries, and also an abundant growth of new elements in the contractile layer of the arterioles: changes which (as affecting the perviousness and contractility of the vessels) may of course, in their turn, be productive or partly productive of other lesions.

I would connect Dr. Klein's observation of these changes, as incidental to scarlatina, with his previous but less elaborated observation of like changes in cases of enteric fever. Diffused bloodvessel-changes, started in that inner surface of the vessels which has immediate contact with the circulating blood, can hardly not be ascribed to the blood as their cause; and moreover, in both the diseases here referred to, grosser blood-change is occasionally attested by clots which form in the course of the circulation, and become impacted as plugs (so-called *emboli*) in the smaller vessels. The tendency to form "emboli" is known to be likewise an attribute of the septic infections; and at least in them it seems certain that the clotting-process is determined by minute masses of shaped zymotic material which act as nuclei for such concretion.

Dr. Klein has not hitherto found in scarlatina anything which he can confidently regard as a microphytic contagium; for, though he no doubt did see, in some cases, in special combination, an abundant presence of well-marked micrococci, this was only where the circumstances rather favoured a supposition that the micrococci were of secondary occurrence; and he for the present reserves his opinion with regard to the doubtful appearance of micrococci which he found in the scarlatinal skin at an early stage of the disease.

MEDICAL OFFICER'S REPORT.

4. Dr. Klein's final paper (App. No. 4) is a summary account of some studies which he has made of a certain infective Fever of Swine. The special reason for this research was that the disease in question had been supposed to be identical with the enteric fever of the human subject; and hope was entertained that therefore our studies of the human disease might be usefully supplemented by studies of the brute. In the event this hope was not realised: for Dr. Klein's research soon showed that the two diseases differ in respects which appear to be essential, and the human disease therefore cannot for the present be studied in other than its human relations. But the research, though in that respect fruitless, has given results which in other ways are of much interest, both as contributing to veterinary practice the more exact knowledge of an important disease of live stock, and also as adding a very interesting new illustration to zymotic pathology in general. In the latter point of view I would draw particular attention to Dr. Klein's description of the state of the lungs and pleura in this pig-disease, as regards the plugging of pulmonary blood-vessels and lymph-vessels, as well as small air-tubes, with micrococci, and as regards the extraordinary diffusion of micrococci on the surface of the serous membrane.

5. In the fifth paper of the present volume (App. No. 5) Dr. Creighton reports on such further studies of Cancer as he had made down to the end of the financial year. The report is a chapter in the natural history of those ineradicable and indefinitely-advancing infective growths which in surgical practice are emphatically called "malignant;" and it particularly relates to the intimate anatomical changes which arise in lymph-glands, when cancer, operating from some spot in which it has been of primary occurrence, secondarily spreads its infection to them.

In explanation of the fact, familiar in pathology, that, in the consecutive extensions of cancer in a given affected body, the secondary and tertiary tumours tend to repeat with an exact mimicry the special pattern of the primary tumour, pathologists have had two different surmises as to the nature of the secondary and subsequent processes: one, that such acts of infection are merely of the nature of a transplantation or botanical grafting-process,—that effluent living elements of the primarily-diseased parts, passing into streams of lymph or blood, and carrying with them a strong germ-power of their own, grow indefinitely on their original plan, and as parasites, in the parts to which they are floated, and in which they chance to take root; the other, that not a mere transplantation, but a zymotic process, is signified by the extensions of cancer,—that the elements of the primarily-diseased part have in them a specific ferment-power, by which, if lymph-stream or blood-stream carries them to another part, they enforce on that part, as with a kind of impregnation, that it, deserting its own former textural type, shall grow in a new way with new endowments, so as to become in form and ferment-power a repetition

of the parent tumour. The former of these two opinions was that which, before the beginning of Dr. Creighton's researches, was, I believe, the more generally entertained in this country,* and, while nothing was shown to the contrary, might easily have been judged the more probable (because apparently the simpler) explanation of facts: but Dr. Creighton's report of 1874, on the development of secondary cancer-nodules in the liver, pointed decidedly to the other conclusion; and his present report, on the cancerisation of lymph-glands, speaks again in the same sense. He had, it is true, one class of cases in which he could identify in the diseased lymph-glands characteristic forms, derived in considerable quantity from the primarily-diseased part; and in this class of cases, taken alone, it no doubt was difficult or impossible to determine whether given tumour-forms existing in the lymph-gland were mere colonists derived (with or without multiplication) from the primary disease, or were an essentially new generation to which the gland itself, by reason of its being infected, had given rise. But the ambiguity which in such cases attached to the phenomena because of the large quantity of the foreign material was, in cases of a different class, comparatively absent. In some cases, namely, material which could be identified as coming from the primary disease was present in given lymph-glands in but so small quantity that the behaviour of the individual migrants, or of separate little groups of them, could be advantageously studied; and in the very valuable set of observations where this was done by Dr. Creighton, he saw no signs as of migrants preparing to pass by mere self-augmentation (after the manner of vegetable grafts) into the new growth which was to follow their arrival. On the contrary, in observations which appear to have been the most instructive of the series, migrants, when they had attained their fullest type of character, seemed merely to undergo dissolution in contact with the gland-soil onto which they had been cast; perhaps diffusing into it at the point of contact as the spermatozoon into the ovum which it impregnates; while, contemporaneously with this their dissolution, the contiguous portion of gland-substance straightway began to show in its individual elements that it had become subject to an alien power, under which it must pervert its own growth to those new and destructive issues which are common to cancerised organs. And Dr. Creighton's observations to that sort of effect acquire an additional importance when they are considered in conjunction with a third set of observations which he describes: cases, namely, in which the infected lymph-gland not only gave, so far as he could see, no evidence of having received shaped migration from the primary disease, but in which moreover the signs of its incipient secondary infection were diffused in it so generally and so equably as almost to exclude the thought of mere transplantation.

* See, for instance, the very interesting discussion which was held on the subject of Cancer two years ago at the Pathological Society of London, and particularly the admirable paper with which the late Mr. Campbell De Morgan then introduced the subject for debate.—*Path. Trans.*, Vol. 26.

It seems to me of great interest to pathology, in some of its most promising relations to the future improvement of practice, that researches like these which Dr. Creighton has begun should be followed to their very utmost yield; and in view of the high qualifications with which Dr. Creighton had been prosecuting these researches, I found cause for particular regret in learning from him towards the close of the year's work here reported on that I might not propose to your Lordships his further continuance in the work.

6. The last paper (App. No. 6) in the present volume is by Dr. Thudichum, continuing his former reports by a provisional account of certain further studies which he has made of the Chemical Constitution of the Brain. Though Dr. Thudichum's work in this investigation has been and is continuous, yet, having regard to its very great extent and its extraordinary difficulty, he does not anticipate that for the next two or three years he will be in a position to give his concluding report on it—a report as comprehensive as that which he submitted two years ago, and containing also his pathological applications of the study; but pending this completion of the entire scheme, there are results of each year which admit of being separately stated; and, just as last year so again now, Dr. Thudichum has presented an interim report with much highly interesting detail in it.

The report chiefly occupies itself with the intimate chemistry of certain of the complex bodies which were described in the former report as immediate principles of the brain, particularly of those of the so-called *cerebrine* (nitrogenous) series; studying, in regard of each such principle, what is its exact eventual yield of elements, and what its exact process of break-up, under artificial chemical treatment. The general importance of this kind of study, as conducing to the interpretation of the chemical changes which are effected by disease in the living body, and as indeed often an indispensable clue for such interpretation, is, I believe, now generally recognised among pathologists; and there are points in the present paper which seem to me strikingly to illustrate it. Thus, the fact, now clearly established by Dr. Thudichum, that sugar is apt to arise as one of the decomposition-products of cerebrine, is highly suggestive in relation to the familiar occurrence of so-called "amyloid bodies" in the diseased nerve-centres of persons who have suffered certain sorts of paralysis, and perhaps also (in a different way) in relation to one interesting section in the obscure ætiology of diabetes; and, in another direction, it is equally suggestive to find that the new crystalline alkaloid which Dr. Thudichum exhibits as a product of brain-destruction, appears to be of intimate affinity with certain chemical compounds which are known as contents or derivates of bile.

Finally, my Lords, adverting to the fact that my tenure of office under your Lordships did not terminate till nearly two months

after the end of the period to which the foregoing report relates, I believe it may be right for me here to state that, during these two months, no work, except such as was of the nature of continuation-work, was undertaken in this branch of your service: for your Lordships had, for parliamentary reasons, determined that you would not till late in the session move Parliament for the usual annual grant for the Scientific Investigations; and under these circumstances the programme which I had in readiness for your Lordships' consideration, with regard to work to be done in the new financial year, necessarily remained in great part in abeyance. I may perhaps be permitted to mention that, among the diseases which I was hoping this year to submit to systematic investigation (in addition to those in regard of which our previous work had to be continued or extended) the first was Rheumatic Fever; and I would also mention that our studies of the obscure problems of zymotic pathology had at so many points (as various sections of the present volume may illustrate) made us aware of the insufficiency of present knowledge of the Natural Ferments of the living animal body, that I was further hoping with your Lordships' sanction to initiate a systematic study of this very difficult physiological subject-matter.

Though now myself removed from further active participation in the medical service of the State, I must continue to feel warm interest in whatever shall promote the progress of that service; and your Lordships, graciously crediting me with this, were so good as to inform me, on my leaving office, that Government intends to continue these investigations. The connexion of them with your Lordships' Medical Department was always felt by me, while in office, as an invaluable aid, co-operative and consultative, in directions where my own working-power (under prior claim of other engagements) necessarily fell short of my wishes; and I daresay that, by my successors under the Local Government Board, the privilege of the official association with scientific research will be appreciated as highly as it was by me. As for the general value and promise of that kind of work in its bearing on the progress of Medicine, I entertain the strongest conviction that, in regard of all antagonism to disease, whether with preventive or with curative measures, and whether by official or by private hands, Medicine's best prospects of increased success are inseparable from such studies of exact science, and that, in proportion as the pathological insight becomes more clear, the growth of practical power will certainly follow. The investigations which have been made under your Lordships' authority have, I need hardly say, only pretended to deal with selected portions of the vast subject-matter of Pathology. Their distinctive aim (as explained in a former report) has but been to supplement, in particular matters and methods of research, other and ordinary agencies of medico-scientific progress: in directions, namely, where research, if it is to succeed, requires systematic and continuous labour extending over long periods of time—labour, not only inconducive to immediate pecuniary profit, but perhaps involving much cost; and

where, such being the conditions, it can hardly be expected that the study, however great its eventual importance, will be adequately cultivated by private investigators. That the investigations, instituted by your Lordships on that limited basis, have even in these few years been of very real instructiveness to the Medical Profession in this country, and that, besides such direct gain of knowledge as they have given, they have very greatly stimulated the general spirit of pathological investigation among us, will not, I believe, be questioned by anyone who knows the medico-scientific records of the time; and in view of their intended continuance, I would express to your Lordships, though now but as an individual practitioner, my thankfulness for the aid which Government will thus be giving to the culture of the Profession to which I belong.

I have the honour to be, my Lords,
Your Lordships' obedient humble servant,
John Simon.

London;
February, 1877.

APPENDIX.

No. 1.

Dr. Sanderson's Report of a further Investigation of the Properties of the Septic Ferment.

Introduction.

The experimental inquiry, of which an account is given in the following pages, was undertaken for the purpose of obtaining more precise information as to the nature and properties of the poisonous substance to which septic liquids owe their virulence.

It has been long known that the aqueous infusions of putrid animal tissues, as for example flesh, produce, when introduced into the circulating blood of the higher animals, certain characteristic febrile and other symptoms which are recognised as those of septic infection. These symptoms were first studied early in the present century by Gaspard, and subsequently by Magendie. In more recent times they have been made the subject of more precise and extended investigations by Panum,* by Otto Weber,† and finally by Bergmann and his pupils.‡

Bergmann§ was led by his researches to infer that the septic poison is a chemical body held in solution by the water of infusion, and accordingly undertook, in co-operation with his colleague Professor Schmiedeberg, researches with a view to its separation by chemical methods. The results of those inquiries are well known. A product was obtained which was believed to be a pure substance, and called *sepsin*. The most characteristic fact relating to it was that when its solution was introduced into the living organism, it produced a pyrexia of several hours' duration, of which the temperature curve corresponded so closely with that of the pyrexia produced by the injection of small doses of septic liquids, that the identity could not be mistaken. This curve has been since often referred to as the sepsin curve by pathological writers.

Twelve years before Bergmann wrote, the subject had been investigated by Professor Panum of Copenhagen; as however his researches were published only in Danish, they failed to exercise their due influence. Subsequently (in 1863), a short account of the work was published in Virchow's Archiv by the author, who further, in 1874, contributed a complete paper on the subject to the same journal. The question to which Panum's attention, particularly in his earlier researches was chiefly directed, was that of the participation of the minutest living forms in the production of the symptoms of septichæmia. "Is "it the case," he inquired, "that the microscopical organisms which "are always present in putrid liquids, stand in such relation with

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* P. L. Panum, Bibliothek for Läger, April 1856, pp. 253-285. Virchow's Archiv Bd. 27 (1863). Experimentelle Untersuchungen zur Physiologie und Pathologie der Embolie, Transfusion und Blutmenge, Berlin, 1864.—Virchow's Archiv Bd. 60 (1874).

† Otto Weber, Experimentelle Studien uber Pyæmie, Septicæmie und Fieber. Deutsche Klinik, 1864–65.

‡ Bergmann, Das putride Gift und die putride Intoxication, Dorpat, 1868.—Zur Lehre von der putriden Intoxication, Deutsche Zeitschrift für Chirurgie Bd. I., p. 376.

The researches of Bergmann's pupils are embodied in a series of academical dissertations of the University of Dorpat, printed between the years 1866 and 1869, by Weidenbaum, von Raison, Petersenn, Schmidt, and some others.

§ Bergmann und Schmiedeberg, Ueber Sepsin. Centralblatt, 1868, p. 497.

"the group of symptoms which are observed when such liquids "find their way into the circulating blood, or into the tissues, that "these symptoms cannot present themselves, if the infecting liquid "is either deprived of its organisms, or subjected to some process by "which their vitality is destroyed." This question Panum answered in the negative. Approaching the subject with a decided bias in the opposite direction, derived from the consideration of the then recent investigations of Helmholtz as to the intimate relation between the chemical process of putrefaction and the morphological changes which are associated with it, he was led, by the study of the nature and development of the symptoms themselves, to doubt whether, granting that that relation were admitted to be completely established, there was sufficient ground for applying the conceptions founded on it to the explanation of pathological actions. Thus, for example, the easily recognized fact that in septic poisoning there is no period of incubation, that the introduction of the deleterious agent into the circulation is immediately followed by the manifestations of its action, seemed altogether irreconcilable with the hypothesis that any such multiplication of virulent material as is supposed to constitute the processes of specific infection, takes place in the infected organism. At the same time he fully recognised that there might be other ways in which these living particles might act morbifically, so that the possibility of their pathogenic action could not be entirely disregarded.

These were the considerations which led Panum to undertake his investigations. It is to be remembered that at the time that he did so, the "germ theory" had not been heard of, that no one had written about "microzymes," and that bacteria were familiar only to morphologists. He had the merit, not only of recognising clearly the importance of the pathological questions which have since become associated with these now familiar expressions, but of making a most important step in their investigation. The method he adopted was excellent. Having first carefully studied the pathological process itself so as to determine its characteristics, and to be able to recognise them with certainty, and having ascertained that they were the constant results of the introduction into the circulation of certain kinds of putrid infusions, he set to work to devise a method by which the influence of the particular factor of which the potency was in question, namely the living organisms contained in such infusions, could be separately tested. With this view the following plan of experiment was adopted: An infusion of flesh having been allowed to stand in a warm room for two or three weeks, was carefully filtered, then boiled for several hours and finally evaporated to dryness on a water bath. The thoroughly dry residue was then digested first with cold and then with boiling absolute alcohol. After the alcoholic extract had been removed and set aside the insoluble residue was extracted, first with cold then with boiling distilled water, and filtered hot. The aqueous extract, which obviously contained exclusively material insoluble in absolute alcohol, when injected into the circulation of dogs in a number of instances, produced in all, the characteristic symptoms of septic infection. The following experiment may serve as an example of the rest.

The material employed was an infusion, of which 24 cub. centims. (yielding 0·071 gramme of solid residue on evaporation) produced death in six hours when injected into the venous system of a small dog. Thirty cub. centims. of aqueous extract prepared from this liquid in the way above described (of which 10·34 grammes yield 0·004 gramme of solid residue) were injected into the jugular vein of a full-grown dog. It will be sufficient to give a short summary of the symptoms, which

are described in the original with great minuteness. About half an hour after the injection, the animal began to be unwell. About 15 minutes later there were horripilation along the back, and slight twitchings of the muscles of the extremities. Soon after retchings commenced and the ropy saliva was copiously discharged from the mouth. Then followed frequently repeated efforts to discharge fæces, the evacuations being at first natural, then accompanied with much mucus. At the end of two hours the pulse was accelerated, and the pupils were strongly dilated, and the depression was already so great that the animal was unable to stand, the alvine symptoms remaining as before. After the fourth hour the dog began to improve. The following morning it was willing to take food, and was rapidly recovering. It was then killed by pithing and immediately dissected. The only pathological appearances observed were those referable to the intestine. The mucous membrane of the duodenum exhibited tracts of congestive hyperæmia, and it was so much swollen that the patches of agminate glands appeared as insular depressions.

On these facts Panum comments as follows:—"It appears to me hardly "possible that anyone, in face of these observations can seriously believe "that here, notwithstanding the filtration, the boiling prolonged for "hours, the evaporation to dryness at the boiling temperature, the "digestion with cold and boiling absolute alcohol, the extraction with "boiling water, and the final filtering, living organisms were still present, "which were not destroyed;" and concludes, "That it may be regarded "as a completely established fact that there exists in putrid fluid a "specific chemical body which is soluble in water, and is endowed with "the property when introduced into the circulating blood, of calling "into existence that peculiar group of symptoms which are recognised "as those of septic infection . . . . retaining that power, notwith-"standing that the liquid is exposed to methods of treatment of such "a nature as to annihilate or destroy the vitality of whatever living "organisms might previously have been present."

Notwithstanding that the terms in which these conclusions are expressed may be open to cavil, any candid person who is fairly acquainted with the discussions which have taken place during the twenty years which have elapsed since they were arrived at, will readily admit that it would have been better for pathological science if they had not been so much overlooked, for the facts on which they are based are quite irreconcilable with the often too carelessly received assumption, that the process of septic infection is dependent on the development of a living contagium.

It was not for the purpose of giving new and additional weight to the testimony of Professor Panum (as to the accuracy of which I could not entertain a moment's doubt) that I undertook the present inquiry, but chiefly in the hope that proceeding from the point to which he had attained, I might be able to advance a step further. I anticipated that whether the poisonous agent was simply a chemical product of this septic process or was endowed with organic form, I could be certain of obtaining it in a condition of great concentration by adopting a method founded on Panum's, and that I should thus be in the most favourable position for investigating its properties and physiological actions.

The question that specially interested me was that of its solubility. In my researches on contagium, published in 1870, I had arrived at the conclusion, which I think I may venture to say has now been very generally accepted, that every contagium consists ultimately of particles not soluble in water. It being admitted that the deleterious agent in septichæmia does not consist of living organisms, it appeared to me possible

and indeed for several reasons probable, that it would be found to resemble the contagia in being particulate, *i.e.*, that the material, although in the ordinary sense soluble in water, might yet consist of particles so minute as to be incapable of so scattering light as to render the liquid in which they are suspended opalescent, and to be irremovable by any of the ordinary methods of filtration.

In order to determine this important question I filtered liquids prepared in the same way as those of Panum through porous porcelain under pressure, employing a method which will be fully described in the following pages. The result was in so far in accordance with my expectations that I found that changes were produced in the liquid extract which were of such a nature as to deprive it simultaneously of its offensive smell, its poisonous action, and of its remarkable power of generating bacteria. That these three changes stood in anything more than concomitant relation to each other cannot of course be asserted there is no sufficient ground for regarding them as attributes of one and the same substance.

Before filtration, the extract, notwithstanding that it is perfectly limpid, always exhibits under high powers of the microscope, certain sharply-defined particles. These bodies, which are of such extreme minuteness as to be only just within the limits of microscopical visibility present no recognisable constant characters either of form or size, so that I am entirely unable to attribute to them any morphological significance. They are entirely absent in liquids which have been passed, even once, through porous porcelain.

The fact has now been proved that virulent septic liquids, even when absolutely free from bacteria or their germs, can be deprived of their virulence by filtration through porous porcelain, but the greatest caution must be used in drawing inferences from it.

The only safe form indeed in which any conclusion can be expressed on the subject is the negative. From the mode of preparation, it can scarcely be supposed that the agent is a living organism. It can further be stated that it is not an albuminous compound, for the absence of bodies of this class is proved by the chemical properties of the liquid before filtration. Its complete removal by filtration renders it probable but by no means certain, that it is not a crystalline body, soluble in water. The only group of bodies to which its properties suggest comparison is that of the so-called "unformed ferments."

EXPERIMENTAL INVESTIGATIONS.

Preparation.—A quantity of finely-divided fresh muscle was macerated in water for 14 days. The liquid was then strained off and evaporated to dryness on the water bath. The residue, reduced to a fine powder, was digested for an hour or more in seven parts of cold methylated spirit, and afterwards boiled for ten minutes in the spirit. It was then collected on a filter and carefully dried at a temperature of 80° until it had entirely lost the alcoholic odour. The insoluble alcoholic residue thus obtained was digested for an hour in from eight to ten parts of cold distilled water, and filtered immediately before use.

Chemical Character.—When prepared in the above manner the liquid is nearly limpid and of a pale straw tint. It has a disagreeable odour and a slightly acid re-action. Its specific gravity is about 1,02* and it yields on evaporation at 100° C. from two to two and a half per cent. of solid residue.† When heated it becomes slightly turbid

* The specific gravity varied in different specimens from 1020·9 to 1029·7.

† The mean of five estimations of quantities prepared at different times 2·1604 %

milky, but on the addition of a few drops of nitric acid again becomes perfectly clear. The addition of acetic acid and potassium ferrocyanide produces no reaction. Heating the extract after adding a few drops of nitric acid slightly deepens the colour, and the addition of a few drops of ammonia, after cooling, causes a deposit which, under the microscope, is seen to consist of feathery crystals, having all the characters of ammonio-magnesic phosphate. None of the other tests for albuminoid substances gave any indication of their presence.

Organic Characters.—The freshly-prepared liquid contains no bacteria, but a greater or less number of very minute shining spheroidal motionless bodies are constantly found in it, to the presence of which its faint opalescence is doubtless due. Exposure to the air, even for a very short time, is sufficient to induce the presence of bacteria. When the extract was kept in sealed tubes, at a temperature of 38° C., bacteria developed in it with extraordinary readiness.

It thus appears that the septic extract is remarkably fertile in relation to bacteria, *i.e.*, that these organisms originate in it with very great facility. In this respect it resembles those artificial cultivating liquids containing peptones which have been lately employed by Huizinga, Gscheidlen, Samuelsohn, myself, and others in experiments relating to the question of spontaneous generation. That, when freshly prepared, it is free from living organisms can scarcely be doubted, for not only does the most careful microscopical examination fail to bring any such organisms into view, but the material from which the extract is prepared has been immediately before thoroughly boiled in alcohol, a process which bacteria can scarcely be supposed capable of surviving.

In order to ascertain whether the extract, although free from living bacteria, owed its fertility to its containing particles of such minuteness as not to impair its transparency, the following experiments were made :—

First Series.—1. Two tubes, about four inches long, were drawn out and heated in the flame of the blow-pipe to a red heat. They were then sealed hermetically in the usual way. On cooling they were partially filled with the extract by breaking off their finely-drawn ends under the surface of the liquid, and were immediately sealed up by the blow-pipe. No. 1 was then placed in the warm chamber, at a temperature of from 35° C. to 38° C. Its contents were perfectly transparent. At the end of twenty days the liquid had become turbid, and on opening the tube the gaseous contents escaped explosively. The liquid was still slightly acid ; it was very fetid and teemed with organisms, namely, short rods, dumb-bells, and spheroids. Tube No. 2 was, previously to being placed in the warm chamber, heated to 110° C. and became slightly milky. On being opened at the same time as No. 1, there was no evolution of gas, and the liquid remained free from organisms.

Second Series.—Four vacuum tubes were prepared in the same manner as those used for the former experiment, and precisely the same method of filling and sealing was adopted. No. 1 was filled with freshly-prepared pyrogenic extract. No. 2 contained the extract filtered once through a porous cell.* No. 3 contained extract which had been

* The porous cells employed for filtration are the cylindrical ones in common use for voltaic elements. The filtration is effected as follows: The liquid to be filtered is introduced into a beaker just large enough to contain the cell. Into the mouth of the cell an india-rubber cork is fitted, perforated by a glass tube. The outer end of the tube is brought into communication with a mercurial air pump by means of a flexible connector of thick-walled vulcanised india rubber. The cell so attached is

filtered twice through a porous cell. In No. 4 was extract which had been passed three times through a porous cell.

These four tubes were placed in the incubator at a temperature of 38° C., and were examined on the tenth day. No. 1 exploded slightly, when its neck was broken off. The liquid was turbid, and filled with actively moving organisms, viz., short rods, dumb-bells, spheroids, and a few short chains. No. 2 exploded but very slightly. To the naked eye its contents did not present any marked turbidity, but when examined microscopally a small number of the same kind of organisms was found as in No. 1. Tubes 3 and 4 contained no organisms.

In order to determine whether the extract, though itself free from living bacteria, possesses, even in the fresh state, the power of determining their development in other liquids, the following experiments were made by the method of impregnation.*

The cultivation liquid used was serum. In order to obtain it under conditions which would, as far as possible, preclude any accidental impregnation of it by means of organic germs, the following plan was adopted :—A glass tube, closed at one end, heated in the flame of the blow pipe, and having its orifice plugged while cooling with cotton wool, was used for the collection of blood from the artery of a rabbit. During coagulation the plug of cotton wool was again inserted. On the following day the serum (about 8 c. c.) was collected and placed in four test tubes, which had previously been heated in the flame of a Bunsen lamp. Three of these tubes were then impregnated with a single drop of the pyrogenic extract, and their orifices were closed with cotton wool. The fourth tube was not impregnated, but the orifice was closed in the same manner as the others. The tubes were then placed vertically in a shallow dish containing a little water, covered by a bell jar, and introduced into the incubator at a temperature of 30° C.

At the end of two days the three impregnated tubes were quite turbid, while the unimpregnated one remained clear. In the former, microscopical examination revealed the presence of a great number of organisms, viz., spheroids, rods, dumb-bells, and chains. In the latter, no organisms could be detected.

Physiological Action.—In the investigation of the physiological or toxical action of the pyrogenic extract dogs were exclusively employed, for the following reasons :—I had ascertained by preliminary experiments that in the dog the symptoms produced are remarkably constant as well as characteristic. In the smaller rodents (the only other animals at my disposal) I had found not only that the effects are inconstant, but that

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plunged into the liquid contained in the beaker, and exhausted by a few strokes of the pump, the process being repeated, if necessary. In a few hours great part of the liquid will have filtered through the wall of the cells into the interior. The most perfect porous cells were selected. At first very thick cells were chosen, and the filtration was conducted through the lower part of the cell only, but it was afterwards found that by using thinner cells and repeating the process, perfect filtration could be obtained in a shorter space of time. After filtration, the specific gravity of the liquid was reduced to 1008·9 or 1009·21. It still retained its slight acid re-action, but was nearly colourless and odourless. Cells once used for filtering could be employed again after calcination. When the liquid was passed through three new porous cells in succession it was always found to be inert.

* This method consists in adding a drop of any liquid or substance to be tested as to its fertility, to some other so-called "cultivation liquid," in respect of which it is known that, although capable of supporting bacterial life, it is not endowed with the property of originating it. My first experiments by this method were made in 1870 with Pasteur's solution. Subsequently I used Cohn's solution, which differs from Pasteur's chiefly in the absence of cane sugar. For the present purpose serum was preferable, as being nearer in its character to the liquid under investigation.

in these creatures the febrile process differs in respect of features more or less essential, from the same process in man; and in particular that, for reasons fully explained in my paper on fever, temperature cannot be used in them as a criterion of the intensity of the febrile disturbance.

The mode of introducing the pyrogenic extract into the circulation was as follows:—A subcutaneous vein having been exposed to the extent of about an inch, the flow of blood was arrested in it temporarily by compression with the finger, the vein wall was pierced by the cannula of a syringe for hypodermic injection, of which the capacity was 5·16 cub. cent., and the requisite quantity was injected.

If more than 5 cub. cent. were required, the syringe was disconnected and refilled without disturbing the cannula. After the injection the cutaneous incision was brought together with sutures, and always healed satisfactorily.

As the purpose of this investigation was to determine to what extent the activity of the septic extract is dependent on constituents which can be removed by mechanical means, it will be convenient first to give an account of the symptoms produced by the clear extract when prepared as above described, and repeatedly filtered in the usual way through paper, and the same liquid after it has passed through porous porcelain under pressure.

Section I.

Action of the filtered Extract.

The symptoms produced in dogs by the injection of pyrogenic extract were as follows:—The first symptom was shivering, more or less marked, continued for several hours, and accompanied by a rise of temperature amounting to 2° C., or even 3° C., the maximum being usually reached at the end of the third hour after the injection. Bilious vomiting and mucous diarrhœa were always observed about the time at which the temperature was highest, and continued for some time after it began to fall. In addition to the mucous diarrhœa there was frequently a considerable amount of intestinal hæmorrhage, and it was characteristic that the introduction of the thermometer into the rectum produced on each occasion tenesmus. In most cases thirst constituted a marked symptom, but if the animals were allowed to drink much water the retching and vomiting were greatly increased, and the water was brought up again almost as soon as swallowed. Usually after the end of the third hour, but never later than the end of the fourth hour after the injection, the symptoms began to subside, the temperature fell almost to the normal, and the vomiting and diarrhœa ceased. In the course of five or six hours with the exception of an occasional slight shiver and some languor, the animal appeared to have recovered. In less than twelve hours after the injection the animals had become quite lively and were anxious for food.

By way of example, the following case, in which a full grown and healthy animal was employed, may be given as very fairly representing the other experiments.

A healthy full-grown dog, weighing 8,264 grammes was infected by injecting 10·32 cub. cent. of pyrogenic extract into the saphena vein in the manner already described. His temperature, previously to the injection, was 38°·7 C. The injection was completed at 4 o'clock p.m., and immediately after the animal became very restless, was salivated, and appeared to suffer from nausea. One hour after the injection the temperature had risen to 40°·1 C., and on withdrawing the thermometer

from the rectum a small quantity of mucus was passed. The animal appeared very ill, was shivering, and at each inspiration uttered a peculiar whining moan. At 6 p.m. the temperature had increased to 40°·4 C., and now there was well marked mucous diarrhœa with tenesmus. The highest temperature, viz., 41° C. was observed at 7 p.m., all the other symptoms, but especially the shivering, being well marked. Four hours after the injection the temperature had fallen to 40°·4 C., but the other symptoms continued, and vomiting had also occurred. During the fifth hour the temperature further declined to 39°·9 C., the shivering was subsiding, the respiration had assumed a normal character, but the animal still appeared suffering. He was very dull, and refused food, stood with his back arched and tail depressed, his nose was hot and dry. On the following morning his temperature was normal, and except that he was somewhat dull, he appeared quite recovered.

In the preceding experiment about one cubic centim. and a quarter of extract per kilo. of body weight of the animal, was injected. As the symptoms were characteristic but not excessive, and the recovery was complete and prompt, this proportion was adopted in all future cases. When, however, it was necessary to employ ill-grown or ill-nourished animals, a diminution of the dose was made in consideration of these circumstances, the object being to produce the required result without exceeding it. In a long series of experiments these results were observed without fail, no case presenting itself in which there appeared to be insusceptibility to the action of the poison, and few only in which the symptoms produced were excessive.

The results of similar observations on other animals are shown in the following table in which the date of each experiment, the weight of the animal used, the quantity injected into the circulation, the temperature of the animal before injection, and finally its temperature at successive periods of observation, one, two, three, and four hours after injection are shown.

Table I.

—	Date.	Weight of Dog.	Dose.	Normal.	1st hour.	2nd hour.	3rd hour.	4th hour.
No. 1	Sept. 1st 1874	8,264 grms.	10·32 c.c.	38·6	39·1	40·6	40·2	39·4
„ 2	„ 5th „	4,837 „	5·16 „	38·6	40·0	41·0	41·0	40·8
„ 3	„ 28th „	8,100 „	10·32 „	38·8	40·2	40·6	41·2	—
„ 4	Dec. 23rd „	4,082 „	5·16 „	39·0	39·8	41·2	40·8	—
„ 5	„ 28th „	7,937 „	10·32 „	39·0	40·8	41·9	42·2	42·3
„ 6	Jan. 5th 1875	6,191 „	7·56 „	38·8	39·3	40·0	40·5	40·4
„ 7	March 19th „	6,803 „	8·7 „	38·6	39·8	40·2	40·6	40·4
„ 8	April 16th „	3,061 „	4·0 „	39·0	40·6	40·8	41·3	39·6
„ 9	„ 21st „	6,100 „	5·16 „	39·0	41·3	41·2	40·6	40·4
„ 10	May 4th „	3,130 „	5·0 „	38·8	39·2	39·8	40·0	40·8
„ 11	June 1st „	7,257 „	9·5 „	38·6	39·4	40·7	41·4	40·6
„ 12	Jan. 21st 1876	7,937 „	10·32 „	38·8	39·6	—	40·8	40·6
„ 13	Feb. 10th „	6,350 „	8·0 „	39·0	40·0	40·5	40·6	40·4
„ 14	March 20th „	5,556 „	5·16 „	38·8	40·2	41·0	—	—

In all the tabulated cases the symptoms were in strict correspondence with those already described in case No. 1. But in one or two instances, not included in the table, the symptoms which presented themselves were different. The animal passed rapidly into a state of collapse, indicated by the fact that the bodily temperature fell. The fall of temperature was accompanied by bilious vomiting, mucous diarrhœa, and

intestinal hæmorrhage, and death followed in a few hours. The following case may be given in illustration :—

A healthy dog, weighing about 6,350 grammes, was injected in the tibial vein with 9 cub. cent. of the extract. Before injection the temperature of the animal was 38°·8 C., while an hour after, it had risen to 39°·6 C. and vomiting had occurred. At the end of the second hour the temperature had fallen to 38°·2 C. and the animal was in a state of collapse. There was mucous diarrhœa and the sphincter ani was quite relaxed. The temperature gradually sank to 32°·6 C., when, at the end of the fifth hour the animal died. During the whole period quantities of ropy saliva flowed from the mouth, and masses of mucus passed from the intestine, the breathing being laboured and very irregular. After death the mucous membrane of the intestines was found to be intensely hyperæmic, studded with hæmorrhagic patches, and covered by a layer of blood-stained mucus, which could be easily detached.

The particulars of the above and other similar instances are given in the following table :

Table II.

No. of Animal.	Date.	Weight of Dog.	Dose.	Normal Temp.	Temperature after Injection.						Result.	Symptoms.
					1 hour.	2 hours.	3 hours.	4 hours.	5 hours.	6 hours.		
	1875	grms.	c.c.									
1	April 12th	6,350	9	38°·8	39°·6	38°·2	37°·2	35°·6	32°·6	—	Death in 5 hours.	Vomiting, diarrhœa, collapse.
2	June 4th	4,762	6	38°·8	37°·6	36°·8	34°·8	34°·6	34°·8	—	Do.	Mucous diarrhœa.
3	„ 21st	4,989	5·16	38°·8	39°·1	37°·2	39°·6	39°·4	39°·0	—	Recovery	Salivation, shivering, and bilious vomiting.
4	„ 22nd	4,780	5·16	38°·8	38°·4	37°·2	35°·8	—	34°·5	32°·0	Death in 6 hours.	Collapse.

Among these cases the third is specially worthy of notice as intermediate in its character between the ordinary case in which the bodily temperature rises to that of pyrexia, and the more severe ones. The general symptoms were exceptionally severe, but the temperature was throughout normal. If the action of the poison had been milder, it would have risen; had it been more severe than it actually was, it would have fallen.* The following instance differs from the others only in the prolongation of the symptoms. The injection was effected in the afternoon; late in the evening recovery seemed probable, but it did not continue.

A dog, weighing about 3,175 grammes, had 5·16 cub. centims. of the extract injected into the tibial vein. At 3.30 p.m., before the inoculation, which was then effected, the temperature was 38°·8 C. At 4.30, it was 37°·8 C., and vomiting and mucous diarrhœa had occurred. An hour later there was marked tenesmus, and the temperature was 35°·9 C. At 6.30, the temperature was 35°·8 C., but after this a slight re-action

* This illustrates a statement made in my paper on the Process of Fever, viz.: that in a certain sense it is possible to have fever without pyrexia. In the animal No. 3., which received the same dose of the same pyrogenic agent as the others, in which the temperature rose to febrile (104° or 106° Fahr.), the physiological process was, notwithstanding that there was no pyrexia, as truly febrile as in the others.

took place, and the temperature rose a little, being 36°·2 C. at 8.30 p.m. The animal however was in a prostrate condition, and was unable to stand. The introduction of the thermometer into the rectum caused excessive straining, and protrusion of the intestine. On removing the thermometer it was seen to be covered with blood-stained mucus. The animal was found dead on the following morning. The only striking post-mortem appearance was the intense hyperæmia of the mucous membrane of the intestine, the contents of which were coloured with blood.

The two sets of cases referred to above as severe and mild respectively, differed so much in their heat phenomena that the question might arise whether the severity of the symptoms observed in certain cases was not attributable either to peculiarities in the animals used, to the mere bulk of liquid injected, or to some other cause. That the differences of effect were mainly, if not entirely dependent on the quantity of virulent matter introduced, may be learnt by comparing the symptoms observed when the same dose of the same liquid was administered to the same animal at one time in a concentrated, at another in a diluted state. This comparison gave the following results :—

1. A strong healthy dog, weighing 6,803 grammes, was injected with 8 cub. cent. of the ordinary extract on March 19. The normal temperature was 38°·6 C. At 5.15 p.m., one hour from the injection, it had risen to 39°·8 C., and an hour later to 40°·2 C., the rise being accompanied with shivering, vomiting, and diarrhœa. These symptoms were still present at 7.15, when the temperature had reached 40°·6 C. After another hour the shivering was subsiding, and the temperature had fallen to 40°·4 C. On the following day the temperature was normal, and the animal seemed quite well.

2. On April 28th, the same animal was injected at 3.30 p.m. with the same quantity of liquid, the temperature being just previously 39° C. During the following three hours the temperature was successively 39°·7 C., 40°·6 C., and 40°·6 C. At 7.40 p.m., it had fallen to 40°·2 C. During the whole of this time the animal was very ill, and the usual symptoms, diarrhœa, vomiting, and shivering were present. On the following morning the animal had recovered.

3. On May 5th the same animal was again employed for experiment, and at 5.45 p.m. eight cub. cent. of a stronger extract were injected into the jugular vein. This liquid had been prepared in the same way as that used for the former experiments, but had been evaporated on the water bath at a temperature of from 80° to 85° C. to half its original volume. The normal temperature of the animal was 39° C. After injection the temperature in successive hours was as follows :—At 6.45 p.m. 37°·7 C., at 7.45, 37°·6, at 8.45, 37°·8, and at 9·30, 37°·6 C. During the whole period the animal was shivering, had diarrhœa, and passed blood-stained mucus. At the end of the time there was marked tenesmus and extreme prostration. On the day following the injection the temperature was normal, but the animal was evidently still ill, refused food, and passed a quantity of blood, showing that the intestinal hyperæmia which is so marked a feature, had existed in its fullest intensity. On the third day there was no hœmorrhage from the bowel, but the animal was emaciating rapidly. On May 8th, at 4 p.m. it was dying, and the temperature was as low as 28° C. The specific gravity of some blood withdrawn from the carotid artery did not exceed that of serum, being only 1033·4.

The only noteworthy post-mortem appearance was the extremely pale and ex-sanguine condition of the tissues. No exudation was found in the pleura or peritoneum. The mucous membrane of the intestines was not ulcerated, but it was of a pale colour and easily detached.

Section II.

Action of the Extract after Percolation through Porous Porcelain.

In the first experiment the Dog No. I. was employed, in which, as before stated, the character of the symptoms produced by an ordinary dose (10 centims.) of the fresh extract had been precisely ascertained. This animal received in all four doses of the extract, of which the first, second, and fourth were filtered in the ordinary way, the third through porous porcelain. The results were as follows:—

Table III.

No. of Animal.	Date.	Weight of Animal.	Quantity Injected.	Extract.	Normal temp.	Temperature after Injection. 1 hour.	2 hours.	3 hours.	4 hours.	Symptoms.
I.	Aug. 28th, 1874	8,264 grm.	10·32 c.c.	Unfiltered	38·7	40·1	40·4	41·0	40·4	Shivering and vomiting. Temp. at 5th hour, 39·9.
	Sept. 1st, 1874	—	„	„	38·6	39·1	40·6	40·2	39·4	Shivering very much.
	„ 9th „	—	„	Filtered	38·4	39·2	38·5	38·3	38·4	No symptoms produced.
	„ 14th „	—	„	Unfiltered	38·8	39·9	41·4	41·5	40·8	Shivering and tenesmus. Temp. at 5th hour, 40·2.
II.	Dec. 30th, 1874	5,329 grm.	8·7 c.c.	Unfiltered	38·8	39·4	40·5	41·6	41·2	Vomiting and shivering.
	Jan. 7th, 1875	—	„	„	38·8	40·0	40·6	41·4	41·6	Shivering and mucous diarrhœa.
	„ 14th „	—	„	„	38·5	40·2	41·0	41·4	41·0	Do. do.
	„ 2nd „	—	8·7 c.c.	Filtered	39·1	39·3	39·0	38·8	—	No symptoms observed.
	„ 11th „	—	„	„	38·4	39·0	39·3	38·8	38·8	Do. do.
III.	„ 2nd „	4,876 grm.	8·7 c.c.	Unfiltered	39·6	40·7	41·2	40·7	40·4	Vomiting and shivering.
	„ 11th „	—	„	„	38·6	39·6	40·4	40·8	40·6	Salivation, vomiting, and dysenteric evacuations.
	Dec. 31st, 1874	—	8·7 cc.	Filtered	38·7	39·0	39·2	39·3	39·0	No symptoms produced.
	Jan. 7th, 1875	—	„	„	38·8	39·6	39·8	39·6	39·2	Do. do.
	„ 14th „	—	„	„	39·0	39·4	39·8	40·0	—	Do. do.
IV.	Feb. 19th, 1876	7,030 grm.	9 c.c.	Unfiltered	39·0	39·4	40·7	41·2	40·4	Shivering.
	April 1st „	—	10·32 c.c.	„	39·0	39·4	40·6	40·3	—	Diarrhœa and vomiting.
	„ 8th „	—	15·48 c.c.	„	39·1	40·1	40·6	41·0	—	Do. do.
	Sept. 16th, 1876	—	9 c.c.	Filtered.	39·2	38·6	38·8	39·0	—	No symptoms produced.
	April 4th „	—	15·38 cc.	„	39·2	39·3	39·2	39·2	—	Do. do.

The transitory and very inconsiderable rise of temperature which followed the third injection in Dog I. is of no significance, for it is known by observation that it is not possible to inject 10 centims. of even the most indifferent liquid without producing this slight disturbance. It is to be noticed that by the end of the second hour the temperature had returned to the standard of health, and throughout the whole period of

observation the animal was in an absolutely normal condition. *It was lively, answered readily when called, and showed no indication of being in the slightest degree affected by the injection.*

The result of three similar series of experiments are exhibited in the same Table. They prove in the plainest way that whatever may be the nature of the poisonous agent, it admits of complete removal by mechanical filtration. By way of supplement to this observation, two series of experiments have been recently made in which an ordinary infusion of putrid muscle was substituted for the aqueous extract of the alcoholic precipitate. I subjoin the tabular summary of these experiments in the same form as the others. They have no bearing on one of the questions discussed in the introduction to this paper, viz., that of the participation of living bacteria in the production of the toxical action; for in this case the liquid swarmed with these organisms. But they exhibit quite as clearly as the other experiments, that if the body to which a putrid infusion owes its poisonous action, is soluble in water at all, it is so in such a sense that it is unable to pass through porcelain.

Table IV.

No. of Animal.	Date.	Weight of Dog.	Quantity injected.	Extract.	Temperature.					Symptoms produced.
					Normal.	1 hour.	2 hours.	3 hours.	4 hours.	
No. 1.	March 1, 1876 -	7,030 grm.	8 c. c.	Unfiltered	39·0	40·6	40·9	41·4	41·6	Vomiting and tenesmus.
	„ 17 „	—	15·48 c. c.	„	39·2	40·2	41·1	41·2	41·4	Vomiting, diarrhœa, and dysenteric evacuations.
	„ 16 „	—	„	Filtered.	39·0	39·6	39·2	39·2	—	No symptoms.
No. 2.	March 7, 1876 -	7,937 grm.	10·32 c. c.	Unfiltered	39·0	39·8	41·0	41·4	40·8	Bilious vomiting and diarrhœa.
	„ 10 „	—	10·32 c. c.	Filtered.	38·6	39·6	39·2	39·2	39·0	No symptoms.
No. 3.	March 7, 1876 -	6,350 grm.	8 c. c.	Unfiltered	39·2	40·2	39·8	40·2	—	Vomiting and tenesmus.
	„ 10 „	—	8 c. c.	Filtered.	39·1	39·8	39·4	39·2	39·2	No symptoms.

No. 2.

App. No. 2.

Dr. Klein in correction of former Paper on Sheep-pox.

Note by Dr. E. Klein, F.R.S., on the Mycelium described in his Paper on Smallpox of Sheep.

In my paper published in 1874 in No. III. of this series of reports, I described and figured on pages 55, 56, 58, and 59, the presence, in the lymphatics of the skin of the pock, of what I regarded to be the mycelium of a fungus which I termed *Oidium variolæ*. Similar features were described and figured in the cavities of the primary and secondary pustules.

My attention has been drawn by Dr. Charles Creighton to appearances, in many respects similar to those described by myself, which he found in preparations of tissues altogether removed from the suspicion of containing fungoid growths of that or any other character; namely, in sections through hardened mammary glands.

A comparison of the two kinds of specimens convinced me that the appearances represented in my figure XI. are not due, as I supposed, to a mycelium in the cavities of the primary pustules, but are products of coagulation of some albuminous or kindred material by the reagent (dilute chromic acid and spirit) that had been employed for hardening the object in question.

The vegetable nature of the other structures—viz. those represented in figs. V., VI., VII., and VIII. (*i.e.* the supposed mycelium in the lymphatics of the skin of the pock), as well as those in fig. X. (*i.e.* the mycelium in the cavities of the secondary pustules)—becomes therefore very doubtful. My doubt as to these being also produced by coagulation is based partly on the similarity between the last-named features and those undoubtedly non-vegetable objects in Dr. Creighton's specimens and also in my fig. XI., and partly on the following circumstances: -(1.)I have lately ascertained that blood, especially in febrile conditions, which is contained in blood-vessels of tissues that had been subjected, in a fresh condition, to the hardening fluid (*e.g.*, chromic acid) presents appearances very similar to branched mycelium-threads to which are attached numerous conidia; the presence of more or less unaltered blood-corpuscles proves their true character. (2.) I have likewise seen that blood-plasma containing globulin or parts of blood-corpuscles, when in lymphatic vessels or kindred spaces, show sometimes in the course of coagulation similar appearances. Whether the greater number of the thread-like structures is due to fibrin or to blood-corpuscles I cannot determine as yet; but it seems to me that both is the case.

In the case of *Variola ovina* it is therefore probable that the supposed mycelium in the lymphatics is due to coagulation of some substance directly connected with blood. My statement, however, remains that in the early stages the lymphatics of the affected skin are filled with micrococci. Of the reality of these organisms (described also by Weizert in the lymphatics of the skin in human variola) there cannot be any kind of question.

App. No. 3.

On the Minute Anatomy of Scarlatina, by Dr. Klein.

No. 3.

Report on the Minute Anatomy of Scarlatina, by Dr. Klein.

This paper contains the results of the microscopic examination of the following organs in Scarlatina: skin, kidney, the tongue, palate, tonsils and pharynx, the œsophagus, stomach, small and large intestine, the larynx and trachea, the salivary and pancreas gland, the liver, the lymphatic glands, and lastly, the spleen. Of these, the skin has been examined in 20, the kidney in 23, the organs of the throat, the liver, spleen, and lymphatic glands have been examined in 8, and the alimentary canal in 3 cases.

Before proceeding to state the results of previous observations as well as my own, it is advisable to give a short account of the cases that have been the source of the above material.

I.—Material for Anatomical Examination.

The following cases have all been under the care of my friend Mr. Shirley F. Murphy, resident medical officer to the London Fever Hospital, to whose great kindness I owe all the material for the present research.

Case 1.—A. B., ætatis 6, was admitted into the London Fever Hospital on January 16th, 1876, after having been ill one day. On admission, evening temperature (E. T.) 104°, morning temperature (M. T.) 106°. Had two convulsive fits in the morning of 17th at 3 and at 8 a.m.; died in the evening of 17th, *i.e.*, after two days' illness. No albumen in urine after death.

Case 2.—J. W., æt. 8, died on April 8th, 1875, some hours after admission into the L. F. H., after three days' illness.

Case 3.—F. C. S., æt. 8, was admitted into the L. F. H. on July 10th, 1875, having been ill two days. On day of admission, M. T. 102°·2, E. T. 104°·6. The whole of body covered with dark s arlet rash. On 11th, M. T. 105°·2, E. T. 104°. On 12th, M. T. 104°·8; died during the day, *i.e.*, after four days' illness.

Case 4.—C. S., æt. 4¾, died on January 24th, 1876, within four hours of admission into the L. F. H., after four days' illness.

Case 5.—A. P., æt. 8, died after four days' illness.

Case 6.—F. T., æt. 11, was admitted into the L. F. H. on January 16th, 1876, having been ill two days. T. 104°·2; on January 17th, M. T. 104°·3. Delirious; dusky rash over body; E. T. 104°. On the 18th, T. 104°·4; very delirious and prostrate; dusky rash; albumen in urine; died in the afternoon, *i.e.*, after four days' illness.

Case 7.—T. H., æt. 28, was admitted into the L. F. H. on April 12th, 1875, after having been ill three days. Faint scarlet rash; E. T. 102°·4. On 13th, M. T. 102°, E. T. 101°·8. On 14th, M. T. 100°·8, was dead early in the morning of 15th, *i.e.*, died after five days' illness. No albumen in urine.

Case 8.—F. T., æt. 4, was admitted into the L. F. H. on November 29th, 1875, having been ill two days. On admission had a dark rash over whole of body. On 30th, E. T. 103°·4. On December 1st, M. T. 103°·2, E. T. 103°·8, no albumen in urine. On 2nd December, M. T. 103°. Rash very dark; died on the 3rd, *i.e.*, after five days' illness.

Case 9.—M. B., æt. 12, was admitted into the L. F. H. on June 28th, 1876, having been ill three days; dark motley rash; throat much inflamed; tonsils sloughing; glands of both sides of neck enlarged; delirious; no albumen in urine. On 29th, M. T. 104°·6, E. T. 104°·8 (after a cold

bath). On 30th, M. T. 105°; died quite suddenly at 3·55 p.m., after five days' illness; no albumen in urine. (For the post-mortem appearances of alimentary canal and mesenteric glands, *see hereafter*.)

Case 10.—M. A. J., æt. 36, was admitted into the L. F. H. on July 10th, 1875, having been ill two days. Has for some time been nursing her child, who was suffering from scarlatina. Slight rash on second day of illness. No rash visible on day of admission; E. T. on July 11th, 105°. On July 12th, M. T. 103°·6, E. T. 103°; no albumen in urine. On 13th, constantly delirious; M. T. 102°·9, E. T. 102°·8. On 14th, M. T. 104°·8, constantly delirious. At noon, T. 106°·2. Died at 3.15 p.m., *i.e.*, after six days' illness. No albumen in urine.

Case 11.—J. B., æt. 1¾, was admitted into the L. F. H. on June 1st, 1876, having been ill one day. Died on the 6th of June, *i.e.*, after about six days' illness; albumen in urine.

Case 12.—H. A., æt. 5, was admitted into the L. F. H. on October 9th, 1875; fading scarlatina rash; no history; T. 103°·6. On 10th, M. T. 102°·4; has a raised rash over legs and thighs. On 12th, M. T. 104°, rash fading, injection of skin uniform, E. T. 102°. On 16th, M. T. 104°; much prostrate; died in the morning, *i.e.*, after about seven days; no albumen throughout illness.

Case 13.—J. H. R., æt. 4, was admitted into the L. F. H. on October 26th, 1875, having been ill four days. On admission has no rash, E. T. 102°·4. On 27th, M. T. 103°·8. Constantly delirious. On 28th, very prostrate; died at 11 p.m., *i.e.*, after six days' illness.

Case 14.—T. L., æt. 7, was admitted into the L. F. H. on October 31st, 1875. No history. On admission has scarlatina rash over whole body. T. 101°; on November 2nd, rash still present; M. T. 102°·1, E. T. 103°. On 3rd, rash less. On 4th, rash nearly gone; albumen in urine; M. T. 101°·8, E. T. 103°·6. On 5th, constantly delirious; much prostrate; M. T. 101°·4, E. T. 103°. On 7th, urine still albuminous; M. T. 101°, E. T. 103°·8. On 8th, no albumen in urine; M. T. 102°, E. T. 102°. Died on 9th, *i.e.*, after about ten days.

Case 15.—D. F. S., æt. 2, girl, was admitted into the L. F. H. on November 19th, 1875, having been ill one day. Scarlatina rash on whole of body. On November 21st, no albumen in urine, M. T. 101°·2, E. T. 102°; glands of neck much swollen. Died on 28th, *i.e.*, after ten days' illness.

Case 16.—J. D. S., æt. 3½ (brother of the preceding patient), was admitted into the L. F. H. on November 21st, 1875, having been taken ill the day before admission. Has a bright scarlet rash over whole of body. On 24th, rash fading, M. T. 104°, E. T. 104°. Glands of neck much swollen. On 29th, urine albuminous, M. T. 102°, E. T. 104°·2. Died much exhausted on December the 2nd, *i.e.*, after about 11 days illness.

Case 17.—T. D., æt. 14, was admitted into the L. F. H. on October 6th, 1875, having been ill five days. Has a dark patchy rash and appears much prostrate. E. T. 101°. Died much exhausted on 12th, *i.e.*, after 11 days' illness. No albumen throughout illness.

Case 18.—G. C., æt. 5, was admitted into the L. F. H. on October 15th, 1875. Died in the morning of the 16th, after 13 days' illness.

Case 19.—E. W., æt. 8, was admitted into the L. F. H. on September 28th, 1875, having been ill three days. Died on October 12th, *i.e.*, after 17 days' illness. Urine examined after death contained albumen.

Case 20.—G. W., æt. 10, was admitted into the L. F. H. on December 11th, 1875. No history. On admission has patchy scarlatina rash. Died on 27th, *i.e.*, about the end of third week.

Case 21.—H. G. A., æt. 4, was admitted into the L. F. H. on October 24th, 1875, having been taken ill six days ago. On admission has dusky uniform rash all over body. On 27th, glands of neck much swollen, rash no more to be seen; E. T. 102°. From November 1st until November 6th very restless; on the 7th of November suppuration on left side of neck. Died on the 8th, *i.e.*, after 21 days' illness.

Case 22.—A. W., æt. 6, was admitted into the L. F. H. on November 17th, 1875; was taken ill two days previously. On admission has a bright scarlatina rash over whole body. On 20th, rash still present, much inflammation of fauces; much prostrate; delirious. M. T. 101, E. T. 102°. On December 9th, glands of left side of neck much enlarged. No albumen in urine. Died on 11th, *i.e.*, after 26 days' illness.

Case 23.—E. F., æt. 9, was admitted into the L. F. H. on September 28th, 1875, having been ill since the previous day. On admission has a bright scarlatina rash over the whole body. On 26th of October urine contained albumen and remained so until the 30th; glands of neck much enlarged. From 31st until 2nd November no albumen in urine. Since the 3rd of November suffered from pneumonia, and died on November 10th, *i.e.*, 44 days since first taken ill from scarlatina.

The material used for microscopic sections was removed from the dead body as soon as possible after death, and hardened in a mixture of two parts of one sixth per cent. chromic acid and one part of methylated alcohol. The hardening process was completed (after about a week) in pure methylated alcohol.

II.—Microscopic Examination of the affected Skin.

A. *With special reference to the above cases.*

I propose to take the different cases in the order of their duration of illness, *i.e.*, in the same order in which they have been enumerated above, commencing with case 1, of two days' duration, and passing on to cases of three, four, five, &c. days' duration; and I propose to describe, in regard of each case, the microscopical appearances of the skin in parts which had been affected with eruption. After the description of the individual cases, a general summary will be given of the changes of the skin in the different periods of the disease.

Case 1.—The epidermis slightly thickened, the layers of the stratum corneum somewhat loosely attached to each other. Many cells of the superficial as well as of the deeper layers of the Rete Malpighii contain double nuclei or nuclei in the act of division, thus indicating that there is probably also a multiplication of the epithelial cells themselves. The chief feature of interest in the epidermis is the presence of cavities of different sizes at the boundary between Rete Malpighii and stratum corneum; they project with a convex surface towards the latter. The larger of them contain a more or less uniformly granular matter, and a few larger droplet-like structures among them. The contents appear in hæmatoxylin preparations of a slight yellowish tint. The granules of the former are of very uniform size, and certainly give one the impression of a collection of micrococci, *i.e.*, zoogloea. The appearances have been represented very accurately in Fig. II. The question of great importance is, of what nature is the material contained in these cavities? In the first place, it may be merely exuded plasma that has accumulated in cavities in the epidermis, there being, as will be mentioned below, much hyperæmia in the skin; that is to say, it may be that we have before us on a microscopical scale, the vesicles of a

iliary eruption, with their contained exudation coagulated by the ardening agent. I cannot disprove that it is so; I can only say hat with the naked eye there was nothing to be observed of a miliary ruption.

Professor Thomas, in his article on Scarlatina (Ziemssen's Cyclo- ædia of the Practice of Medicine, vol ii., English translation, . 149 and following), says on page 162, "Miquel reported to the French Academy that he had inoculated a number of children, who had never had the disease, with the contents of vesicles from scarla- tinous patients; thirty hours after, there appeared at the place of inoculation a red areola, which corresponded in every respect to the scarlatinous eruption; this redness increased for three days, and disappeared on the fifth day. The inflammation was not traumatic, for a second inoculation in the same individual had no effect.' 'aking into consideration the present state of the doctrine of conta- ion, it is interesting to inquire, with regard to the granules present the epidermis of scarlatinous eruption, whether they possess any efinite characters which would permit of their being regarded as icrococci and not merely as coagulated plasma. As has been ready stated, the material does not stain blue with hæmatoxylin ke many micrococci situated on or near a free surface, but appears, robably by contrast with the violet-blue colouration of the specimen ith hæmatoxylin of a slightly yellowish tint. But the fact or s not staining with hæmatoxylin cannot be decisive, as I have ot unfrequently seen undoubted masses of micrococci which did not come tinted blue by logwood. It appears to me that this depends a variety of causes, one of which is the nature of the tissue, another ie process to which the preparation had been subjected before it as placed into the staining fluid; thus the masses of undoubted icrococci situated on the surface of the mucosa and in Lieberkühn's ypts of the typhoid intestine, hardened in chromic acid, did not stain all with hæmatoxylin.

If the granular material in question had stained blue I would not esitate for a moment to pronounce it to be composed of micrococci; it has, however, remained unstained it is necessary to see whether ere exist other reasons for saying so. The chemical reaction did ot yield any positive results, for after subjecting the preparation ection of hardened tissue) to the action of caustic potash (35 per nt.), or dilute acetic acid, the granular matter remained unchanged, it then there appeared in the preparation so much additional granular atter—occasionally quite as uniformly and regularly granular as the rmer—that it is quite impossible to arrive at a definite conclusion.

Thus it is impossible to say anything else but that the nature of the aterial in question cannot at present be established with certainty.

Besides these cavities containing the granular material there are her smaller cavities, not larger than one or two epidermis-cells, which o not contain any formed matter, being merely spaces between the ost superficial cells of the Rete Malpighii which are being converted to horny scales; by the confluence of these spaces in a horizontal rection the stratification is effected of the superficial layers.

In the Rete Malpighii are found lymphoid corpuscles, possessing ne or two small nuclei deeply stained by hæmatoxylin, and thus easily stinguishable from the nuclei of the epithelial cells. These lymph- rpuscles may be traced from the papillary layer of the corium, d it must be assumed therefore that they migrate into the epidermis.

We shall return to this question of the infiltration of the epidermis or ithelium with wandering cells from the sub-epithelial membrane more fully

hereafter when dealing with the changes of the mucous membrane of the throat.

At some places these wandering or lymph-corpuscles are only to be met with singly, at others they form small collections.

The chief sign by which the increased thickness of the Rete Malpighii may be recognised at once is the dimensions of the interpapillary processes, these being somewhat longer and more prominent than in the normal skin. Hence also the papillæ of the corium are more marked than in the normal condition.

In connexion with the thickening of the Rete Malpighii may be mentioned the increase of the nuclei of the epithelial cells lining the neck and mouth of the hair follicles; in many instances the nuclei are seen in couples or triplets.

The superficial part of the corium, *i.e.*, the papillary body, contains a greater number of nuclei than normally. They are generally arranged along the venous and capillary vessels, and may be divided into two kinds: (*a*) ovoid transparent finely granular nuclei belonging to the endothelial wall of blood vessels or lymphatics, and (*b*) rounded nuclei, either single or double, staining much deeper in hæmatoxylin than the former, and being surrounded in many instances by a zone of granular protoplasm. The former, viz., the nuclei of endothelial structures, appear more numerous than in the normal parts of the skin; the latter are more abundant in the most superficial parts of the papillæ, whence they find their way into the Rete Malpighii.

In connexion with this last-named fact I wish to mention an appearance which is commonly met with in the Rete Malpighii of the scarlatinous skin as well as in the epithelium of the mucous membrane of the throat in scarlatina, in some parts more distinct than in others. It is this: the individual cells of the Rete Malpighii, chiefly in the deepest and middle strata, appear in our sections distinctly separated by clear transparent canals, intercellular canals, which at some places expand into small lacunæ. Into the intercellular canals the ridges of the ridge-and-furrow cells may be seen to project, without, however, passing right across the canals as represented by Bizzozero, who first described this appearance in the epithelium, and regarded it as a normal feature. From what I stated just now I do not of course with Lott go so far as to say that these intercellular canals do not exist, but on the other hand I do not go the whole length with Bizzozero either, who maintains that those canals in their great distinctness are normal structures. It is beyond doubt that they are very distinct if the sub-epithelial membrane, corium or mucosa, is in a slight inflammatory condition, *i.e.*, if the latter as well as the epithelium are irrigated by abnormal quantities of plasma. Owing to this circumstance the lymph-canal system of the papillary body is very distinct. From these facts it seems to me probable that the intercellular substance (cement substance) of the epithelium, which according to the recent observations of Thoma, Arnold, and Küttner represents the passages through which fluid and formed matter is carried from the sub-epithelial membrane into the epithelium, becomes more fluid and more copious, as far as space is concerned, during this abnormal irrigation; so that the intercellular canals, which contain an abnormal quantity of intercellular substance, appear in hardened specimens much distended and more distinct than in the healthy state. As we shall see very distinctly in connexion with the mucous membrane of the throat, the wandering lymph-cells of the mucosa pass from this latter into the epithelium through the intercellular canals, and accumulating in them cause the appearance of smaller or larger cavities or vesicles in the

epithelium. Fig. XIX., which is taken from a section through a papilla of the tongue of a scarlatina case (*see* explanation of figure), shows the intercellular canals distended at some places to smaller or larger cavities containing wandering cells.

As I mentioned before, we shall meet with these appearances, viz., great distinctness of intercellular canals, and in them migrants which have travelled thither from the subepithelial membrane, very often hereafter in the skin, and especially in the throat, and I wish to repeat that I regard these facts as a consequence and a symptom of the general inflammatory condition of the corresponding membranes.

Among the migratory cells found in the superficial layers of the corium are some that are filled with yellowish brown pigment-granules. From the corium the pigment-granules may be traced into the deepest stratum of the Rete Malpighii, where they form lumps situated in the upper part of the deepest cells, *i.e.*, externally to the nucleus.

The bulb of some large hair-follicles is possessed of several digitate processes composed of small nuclear cells, which form a continuity with, and are therefore outgrowths of, the epithelium of the external root-sheath. The sweat glands show the following changes: the nuclei of the epithelium lining the first part of the duct, *i.e.*, that part which comes off from the coiled tube, are very much increased in number, but also the nuclei of the epithelial cells lining this latter are at some places more numerous than at others. The lumen of the coiled tube is distinct. A few lymph-corpuscles may be seen around the sweat glands; they are, however, much more abundant around the hair-follicles.

The blood vessels appear distended and filled with blood corpuscles, amongst which may be found masses of fibrin.

There is an important point to be mentioned as regards the arteries; it is namely this: in some parts of the muscular coat the nuclei are more abundant than in others, owing to the transverse division of the ordinary staff-shaped nuclei of the circular muscle-fibres into two or three smaller oblong nuclei placed end to end with their long axis. This fact, viz., the division and multiplication of the nucleus of the unstriped muscle fibres of the arterial wall will be mentioned hereafter repeatedly in connexion with the kidney and throat.

Having dwelt at some length on the changes of the epidermis and corium in this case, it will be possible for me to be brief in the description of the other cases. Thus by saying that the epidermis is increased in thickness, the concomitant symptoms are understood at the same time, *e.g.*, nuclei in the act of division or already divided, interpapillary process lengthened, &c., &c.

Case 2.—Epidermis increased in thickness, especially the Rete Malpighii. Intercellular canals discernible; not only the deepest stratum of the Rete Malpighii but also the strata next to it are composed of cells elongated in a direction vertical to the surface. The chief point of interest in the epidermis is represented by the local thickening of the stratum lucidum of Philippi and Schrön, *i.e.*, the horny homogeneous layer between the proper stratified stratum corneum and Rete Malpighii, which is present generally only in some parts of the epidermis, and then only as an exceedingly thin transparent stratum; it contains occasionally the last rudiments of nuclei of the former Rete-cells. The thickening in question of this layer is not at all frequent; it is at one place greater than at another, and varies also in breadth, extending over a smaller or larger area. In Fig. I. is represented a thickening of this kind, extending, as is seen in the drawing, over a considerable area. I may mention that this is the greatest breadth to which I have seen it extend. The thickening is homogeneous, does not show any distinct traces of nuclei,

but is very conspicuous by its containing minute uniform granules. As we shall have repeatedly occasion to mention hereafter, the abnormal thickenings of the stratum lucidum do not present this granulation everywhere, and even not in all parts of one and the same locality. As long as this granulation is examined in sections made vertically through the thickening, and under a moderately high power, they very much look as if they were minute discontinuities which at some places become confluent into larger or shorter fissures between the corresponding strata. Examining them, however, in a horizontal view and under a high magnifying power, it seems more than probable that we have before us real and veritable granules of a very uniform size. We may dismiss at once the idea that these "granules" are identical with pigment granules, which as is well known may be seen not only in the substance of the hair-shaft, but may be traced also occasionally up to the most superficial layers of Rete Malpighii. Nor can it be said, I think, that the presence of these granules is due to amorphous albuminous matter of some kind or other in a coagulated state; for it is hardly possible to imagine that fluid albuminous matter, *e.g.*, exuded plasm (residues of broken up migratory or other cells must be excluded or account of the very uniform size of the granules), remains in that condition in the midst of a stratum which owes its origin to a confluence, as it were, of the superficial scales of the Rete Malpighii, while these are transformed into horny substance. Thus we arrive at the conclusion that these granules may possibly be masses of micrococci. Here again we have to mention that they do not appear to be stained, a fact which renders their identification as micrococci more difficult. And likewise it is difficult to come to a definite conclusion, for the reason that they do not appear to remain unaffected by caustic potash; the swelling up of the matrix in which they (granules) are embedded renders them invisible.

A similar change may be observed in some of the hair-follicles; in some of these the internal root sheath of the shaft of the hair appears to be much thickened, and to contain over a greater or smaller area the same regular granulation as mentioned above.

The nuclei of the epithelium constituting the external root sheath shows nuclei in the act of division or already divided.

The Rete Malpighii of the epidermis as well as the external root sheath of some hair-follicles contains isolated migrants or small collections of them; they are contained in smaller or larger cavities. In the most superficial parts of the Rete Malpighii are found vesicles filled with fluid or with what appear to be smaller or larger fragments of lymph-corpuscles.

The papillæ of corium are distinct and enlarged, the tissue of the latter contains numerous nuclei, most of them belonging to migratory or lymph cells. The "infiltration" with lymph-cells has its seat also in the tissue surrounding the hair follicles and sebaceous glands, and where the "infiltration" with lymph-cells extends from the depth of the skin into the papillary body of the corium, it extends entirely along the hair follicles and venous vessels.

Among the migrants of the superficial parts of the corium large cells filled with brownish pigment granules, and following chiefly the blood vessels, are very conspicuous.

The sweat glands show considerable changes, the epithelium of the coiled tube being loosened, and in many places detached from the membrana propria; in the lumen are contained in some places particles of disintegrating blood discs.

The deeper parts of the corium and the subcutaneous tissue show the interfascicular lymph-canals very marked, probably due to their being

istended by fluid. The blood vessels are distended by, and filled with lood.

Case 3.—The stratum corneum shows already signs of desquamation, arts of it being loosened, and in the act of separating over smaller or reater areas. There are only traces of thickenings of the stratum lucium, and in it indications of granulation. The Rete Malpighii is much ickened, the interpapillary processes being long and distinct, so are lso the pupillæ themselves. Only a very few isolated lymph-cells may e found in the Rete Malpighii. The intercellular canals are, however, ery marked.

The corium of the papillary body is very transparent and shows a onsiderable amount of infiltration with lymph-cells, some of them igmented wanderers, these being chiefly distributed along the blood essels. The blood vessels in the superficial parts of corium distended nd filled with blood. Blood is also present around the blood vessels, hence it extends into the interfascicular lymph-spaces.

The sweat glands show the following changes: the nuclei of pithelium in some parts of coiled tube more numerous than in others; he epithelium at some places loosened and even completely detached rom membrana propria; a few lymph-corpuscles in the tissue around he coiled tube.

Apparent increase of nuclei of muscles of circular coat of arteries.

Case 4.—Epidermis thickened in both its parts, the stratum corneum howing slight indication of desquamation. In a few places the stratum ucidum is slightly thickened, and contains in these parts a few deeply tained staff-shaped nuclei, the epithelial nuclei, and traces of granulaion; a few lymph corpuscles are found in Rete Malpighii.

Intercellular canals, interpapillary processes, and papillæ are in the ame condition as in the former case. Likewise the corium is conderably infiltrated with lymph-cells, chiefly along the blood vessels some of these are quite ensheathed in lymph-cells) and hair follicles.

The sweat glands: at some places an increased number of nuclei of he epithelium of the coiled tube.

The blood vessels are distended and contain blood, amongst which lso a certain amount of finely granular matter may be met with.

Case 5.—Stratum corneum thickened, shows indications of desquamation. Rete Malpighii thickened; stratum lucidum shows thickenngs, some of which contain staff-shaped nuclei, and also uniform ranulations; also these thickenings show signs of desquamation. A ew lymph-cells in Rete Malpighii, in the superficial parts of which they re aggregated even to small clusters.

Infiltration with lymph-cells in corium and papillæ chiefly along lood vessels, the nuclei of endothelium of which are distinctly increased; also the nuclei of the epithelium of the external root sheath f hair follicles increased; at the bulb the external root sheath is possed of a number of longer or shorter digitations composed of small pithelial cells.

The sweat glands show considerable changes: at some places the umber of nuclei of epithelium of coiled tubes is increased, at others the pithelium is detached from the membrana propria and fills the tube ore or less completely, showing at the same time signs of breaking p into isolated nuclear elements.

The blood vessels are distended by, and filled with, blood, fibrin hreads, and numerous colourless corpuscles. The endothelial, as well s muscle, nuclei of arteries appear to be increased in numbers.

Case 6.—Epidermis much thickened, chiefly in the Rete Malpighii. Stratum lucidum slightly thickened at a few places and containing at the same time the remains of the nuclei of the previous epithelial cells. Slight granulation of these thickenings. Papillæ of corium very distinct; their tissue is transparent. A considerable number of nuclei is present in the corium; they are distributed chiefly in connexion with the blood vessels and hair follicles. The nuclei are either oval, large, transparent nuclei of endothelial cells, or deeply stained nuclei of lymph-corpuscles. There are a few migrants in the Rete Malpighii; some of the migrants in the papillary part of corium are pigmented. Pigment is present also at a few places in the deepest stratum of Rete Malpighii.

Blood vessels are distended and filled with blood and fibrin; in the small veins are a good many colourless corpuscles. In the coiled tube of the sweat glands there is no lumen visible, the nuclei of the epithelium in many places in greater numbers than is normally the case.

Case 7.—Epidermis shows no increase; interpapillary processes, however, very distinct and papillæ therefore very marked, long and broad. The stratum lucidum is everywhere well developed, and contains very numerous large granules stained very deeply in hæmatoxylin. The same deeply stained granules are present in the flattened scales of the external root sheath of hair follicles. Pigment present in the deepest cells of Rete Malpighii. Corium contains many nuclei—the nuclei of endothelial cells of blood vessels and nuclei of lymph-corpuscles; the latter are distributed chiefly along the blood vessels and also hair follicles, and to a lesser degree around sebaceous and sweat glands. In the papillæ a few small lumps of pigment; in the corium, in different depths, may be found a few large wandering cells staining extremely deeply in hæmatoxylin. The sweat glands show considerable changes: the nuclei of the epithelium of the ducts distinctly increased in numbers; the epithelium of most parts of the coiled tube completely detached from the membrana propria and more or less broken up, at the same time there is blood more or less unchanged in the coiled tubes.

The blood vessels are distended and filled with blood. In superficial as well as deep parts of corium blood *en masse* is present in some of the perivascular lymphatics. In one instance I have seen an artery surrounded for a considerable distance by a very large space more or less filled with blood, and in another preparation I found the wall of a capillary vessel broken and blood extending along its outer wall for some distance.

The wall of veins and capillaries shows unmistakeably a greater number of (endothelial) nuclei, some of these being constricted or already divided. The interfascicular lymph spaces in the deeper parts of corium and the subcutaneous tissue are very conspicuous.

Case 8.—Epidermis very considerably thickened in all its parts; stratum corneum shows slight signs of desquamation. The stratum lucidum, however, only distinct at the mouth of some large hair follicles, and shows then slight granulation. Rete Malpighii conspicuously thickened, its interpapillary processes long and broad; there is also distinct proliferation of nuclei of the epithelium of external root sheath of hair follicles. In the deeper parts, that is, near the bulb, processes composed of small epithelial cells may be seen in connexion with the external root sheath. Very intensive infiltration with lymph-cells may be observed around the blood vessels of the corium, around the bulbs of hair follicles and sweat glands. Most of them are uninuclear lymph-corpuscles; some contain, however, two or three very small nuclei.

The sweat glands show in many parts of the coiled tube no lumen, this being occupied either by the swollen epithelium or by what appears to be to be a band or cylinder showing a fine and indistinct longitudinal striation, and not dissimilar, therefore, to the so-called fibrin-cylinders in the tubes of the kidney in different forms of nephritis. The dilated blood vessels contain blood and matter composed of coarse bright more or less angular particles, which are very similar to those bright particles that one so often sees in various numbers in healthy as well as in diseased blood taken fresh from man as well as from animals.

Case 9.—The chief features of interest are: (*a*), the thickening of the stratum lucidum, which at some places is uniformly granular; (*b*), the presence of masses of migratory cells at some places in the superficial layers of the Rete Malpighii; (*c*), the same is the case with the epithelium of the mouth of hair-follicles.

Very slight infiltration with lymph-corpuscles of the superficial parts of the corium; the blood vessels of corium distended, and contain blood. The epithelium of coiled tubes detached and more or less distinctly breaking up into granular fragments.

Case 10.—Skin not examined.

Case 11.—Epidermis very conspicuously thickened in all its parts. Stratum corneum showing distinct desquamation. The stratum lucidum is in many places, with and without connexion with the mouth of hair-follicles, distinctly thickened and composed of several horny strata still showing the nuclei of the epithelial cells from which they originated. In some parts the thickened stratum lucidum shows granulation. Rete Malpighii very transparent; distinct signs of germination of nuclei, some of which contain two nucleoli. Some of the nuclei are vacuolated. There is slight infiltration of Rete Malpighii with lymph-cells. Subepithelial tissue, *i.e.*, papillary body, transparent, the papillæ long and distinct; they contain a very great number of lymph cells, and so does the tissue around the blood vessels of the corium in general. The coiled tubes of the sweat glands show in some parts transparent epithelium and a distinct lumen; in other parts the lumen is gone, owing to the swelling up of the epithelial cells; the same applies also to the ducts. Blood vessels in general distended and filled with blood. A few pigmented wanderers may be noticed in the superficial parts of corium.

Case 12.—Stratum corneum thickened; shows desquamation. The stratum lucidum distinct and slightly thickened at some parts, showing at the same time granulation in some of the thickened parts. In the corium a slight increase of nuclei, chiefly belonging to lymph-corpuscles, may be noticed around blood vessels and hair follicles. The blood vessels are distended, and contain much fibrin, arranged so as to form little tufts of radiating short fibres. Some of the nuclei of muscular coat of arteries appear to be in the state of germination. The nuclei of the epithelium of the coiled tubes of the sweat glands in many instances divided. In some parts the tube does not show any lumen on account of its being filled up by the swollen epithelium.

Case 13. — Epidermis much thickened, especially in the Rete Malpighii. In the most superficial layers of the latter, smaller or larger cavities may be noticed, by which the superficial strata of the epidermis become loosened and more or less completely detached from the Rete Malpighii. These cavities are either small and contain no formed particles, or they are larger and contain then a few droplet-like homogenous structures of very various sizes, probably coagulated plasma. The stratum lucidum is much thickened at some places and distinctly

granular; in some parts of it we can still trace the staff-shaped remains of nuclei of the epithelial cells. Some of the nuclei of the cells of the Rete Malpighii are exceedingly large, and contain also one or two large nucleoli. Intercellular canals very distinct in some parts. Papillæ enlarged. Only few lymph-corpuscles are to be met with in the corium, around the blood vessels, hair follicles, and sweat glands.

Case 14.—Stratum corneum thickened and desquamating. There are only a few places where the stratum lucidum is thickened and granular, it contains also a few staff-shaped nuclei. *Similar thickenings are included in the desquamating stratum corneum, i.e.*, in the superficial strata, which are already more or less separated from the surface of the Rete Malpighii.

Only very few lymph-corpuscles are to be met with in the Rete Malpighii. Pigmentation at some places of the deepest stratum of epithelium.

Papillæ of corium very distinct and long.

Directly underneath the epidermis the corium is very transparent.

The tissue of the corium shows infiltration with lymph-corpuscles chiefly around the blood vessels and the root of hair-follicles. In the apex of some papillæ are found occasionally homogeneous highly refractive drop-like masses. It cannot be determined whether these are derivatives of blood contained in vessels. I may mention here that similar masses I have repeatedly noticed in the same places and also, as it seems to me, in the epidermis in several other cases.

The ducts and coiled tubes of sweat gland show in some parts more numerous nuclei of epithelium than in others.

The lumen is not visible everywhere as the epithelium seems to fill up the tube.

The bulb of hair follicles shows the processes of the external root sheath so repeatedly mentioned.

The blood vessels of deeper parts of corium contain blood and fibrin; very marked proliferation of the nuclei of muscle fibres in the coat of arteries.

Case 15.—Skin not examined.

Case 16.—Epidermis shows considerable desquamation of thickened stratum corneum. The stratum lucidum thickened in many parts, granular, and contains particles which stain deeply in hæmatoxylin—remains of nuclei. Similar masses are included in the desquamating layers of the stratum corneum. The same condition is to be observed on some large hair follicles, the hair of which is surrounded near the mouth of the follicle by an exceedingly thickened, granular, internal root sheath; immediately around the hair are closely aggregated deeply stained particles—remains of nuclei—and in some instances the whole surface of the hair is of a uniform deep blue tint in preparations that had been stained in hæmatoxylin. The Rete Malpighii is much thickened. The papillæ of corium very distinct. Infiltration with lymph-cells chiefly around blood vessels and around the root of hair follicles. The arrectores pilorum are exceedingly well developed; there are signs of germination of the nuclei of the muscle fibres.

Blood vessels are distended and contain blood and coarse highly refractive particles, and also little tufts of radiating short fibrin-fibres.

Sweat glands show slight change; in some parts of the coiled tube the epithelium is very transparent and is filling up the tube so that no lumen can be detected.

Case 17.—Desquamation of stratum corneum. The Rete Malpighii is not perceptibly thickened. Pigmented lumps are present in the

deepest epithelial cells external to the nucleus. Corium is only very slightly infiltrated with lymph-corpuscles around blood vessels, hair follicles, and sweat glands. Distinct increase of nuclei of the endothelium of small veins. The blood vessels of the deeper parts of corium are distended and contain blood corpuscles and small irregular highly refractive granules. The epithelium of coiled tubes of sweat glands in some parts swollen so as to fill up the lumen, in others it is breaking up.

Case 18.—Epidermis very much thickened; stratum corneum desquamating. The stratum lucidum distinctly thickened and in many places uniformly granular; similar uniformly granular masses slightly stained with hæmatoxylin are to be met with in the desquamating parts.

The uniformity of the granules forming smaller or larger lumps is very characteristic of micrococci, and the aspect such, that although one cannot fully express its peculiarity in describing it, one can hardly fail to perceive it under the microscope, whatever their chemical character may be.

In Fig. III. I have represented these appearances, and it cannot be denied that the resemblance between lumps of micrococci and the masses in question is very great. More than this I do not venture to say.

Rete Malpighii much increased in thickness. Papillæ of corium enlarged. The superficial parts of the corium are very much infiltrated with lymph-corpuscles, most of these possess two or three small nuclei. The infiltration with lymph-corpuscles is greatest around blood vessels and hair follicles, to a lesser degree around the ducts of sweat glands. Pigmented wanderers are to be met with in the papillary tissue; pigment is present also in the deepest stratum of the Rete Malpighii.

The lymph-canal system of deeper parts of corium very distinct.

In many parts of the coiled tubes of the sweat glands the epithelium is transparent, filling up the tube, in other parts the epithelium is breaking up into granular masses.

Case 19.—Desquamation of layers of thickened stratum corneum. The stratum lucidum is thickened at some places and granular. Similar masses (containing in addition also a few remnants of nuclei) are contained in the desquamating layers of the stratum corneum.

Some of the large hair follicles show the analogous changes, consisting in a thickening of the internal root sheath, which includes remnants of nuclei of epithelial scales, and in many parts also the uniform granulation. Figs. IV. and V. are drawn from preparations obtained of this case.

The Rete Malpighii increased in thickness; many nuclei in state of division; some of the nuclei of the deeper and superficial layers are vacuolated, or shrunk and folded or crescentic. These appearances are to be met with also in specimens of several other cases, but there does not seem to be any regularity in the occurrence of these phenomena.

The papillæ of corium distinct. Much infiltration in the corium with lymph-cells, chiefly around veins and hair follicles.

There is a very conspicuous increase of the nuclei of the endothelium of the smaller veins, many of the nuclei showing at the same time a longitudinal linear mark.

The nuclei of the muscle fibres of the arteries show likewise signs of germination. A similar appearance is presented by some of the nuclei of the arrector pili. The sweat glands are filled up in most part with their epithelium, which in some portions of the coiled tube is detached and even breaking up.

Case 20.—Desquamation of the thickened stratum corneum. Rete Malpighii not conspicuously thickened, on the contrary at some places it is decidedly thinner than normal. In the neck and mouth of hair follicles the internal root sheath is much thickened, granular, and includes even a few deeply stained remnants of nuclei. The external root sheath of the deeper parts of hair follicles is possessed of smaller or larger processes composed of small epithelial cells.

The papillæ of corium distinct and transparent.

The tissue of corium shows slight infiltration with lymph-cells chiefly around blood vessels, hair follicles, and sebaceous glands. The arrectores pilorum very well developed. Distinct lymph spaces around their constituent bundles. The sweat glands show a great number of nuclei; in many parts of the coiled tubes the epithelium is swollen, transparent, and is completely filling the lumen of the tube.

Blood vessels distended, contain blood, fibrin, and granular matter.

Case 21.—Desquamation so intense that at some parts the stratum corneum is altogether gone. The stratum lucidum is thickened at some places more than at others and granular; it contains also occasionally a few staff-shaped nuclei stained deeply in hæmatoxylin. The subepithelial tissue is loose and very transparent. The tissue of corium very slightly infiltrated with lymph-cells, chiefly along the blood vessels (small veins) and hair follicles, and to a slight extent also around sweat glands. Pigmented wanderers are to be met with in the superficial parts of corium; pigmentation also observable in the deepest epithelial stratum.

In some parts of the sweat glands the nuclei of epithelium are more numerous than in others, the epithelial cells at some places almost filling up the coiled tubes. The blood vessels are distended, the deep ones filled with blood, amongst which a few fibrin threads may be detected. Interfascicular lymph-spaces of deep corium and subcutaneous tissue very distinct.

Case 22.—Skin not examined.

Case 23.—Thickened stratum corneum, and also thickened Rete Malpighii. The stratum lucidum is distinct at some places and contains a few brownish pigment granules.

Papillæ of corium distinct. The blood vessels all through the corium are very distended and filled with blood; considerable masses of fibrin in them. In the wall of blood vessels numerous nuclei, amounting at some places to small collections of lymph-corpuscles. A few pigmented wanderers in the papillary tissue.

The sweat glands show little change; in some parts of the coiled tube the epithelium is swollen and filling up the lumen; the capillary blood vessels around the coiled tubes distended and therefore very distinct.

In connexion with the external root sheath of hair follicles are cylindrical processes composed of small epithelial cells.

B.—*General Remarks on the Anatomical Changes of the Skin in Scarlatina.*

From the foregoing it is evident that the descriptions of the microscopic appearances of the eruption, generally given in text books, require additions in several respects. The changes of the skin in the eruption are represented to be those of hyperæmia and inflammatory œdema, more or less well marked in the superficial layers of the skin.

Löschner* speaks of an exudation into the Rete Malpighii containing fluid and formed parts, *i.e.*, cells of various shapes and sizes.

We have in several cases mentioned the presence of lymph-cells in the Rete Malpighii; in fact it appears to be the rule that in the earlier stages migratory cells find their way from the papillæ into the Rete Malpighii, where they may be found isolated or in smaller or larger groups in corresponding cavities. We have likewise called attention to the irrigation of the Rete Malpighii with abnormal quantities of fluid, *i.e.*, plasma, as is evinced by the formation of cavities and the collection of fluid in them in the upper part of the Rete Malpighii, and the great distinctness, *i.e.*, distension, of the intercellular canals.

In addition to this we have noticed in the eruption of almost all stages the increased thickness of the epidermis, and the enlargement of the interpapillary processes; in the Rete Malpighii we have seen distinct signs of division of nuclei and nucleoli (enlarged nuclei, constricted and double nucleoli), thus making it probable that the increased thickness of the Rete Malpighii is due to a multiplication by division of the cells of the Rete Malpighii. In the late cases, however, the Rete Malpighii is found not to be so much thickened. Before the desquamation of the epidermis becomes perceptible in the living subject by clinical observations, the microscope, as we have seen, reveals two important facts: (*a.*) the local thickenings of the stratum lucidum; and (*b.*) the loosening and even detachment of smaller portions of the superficial parts of the epidermis. Those thickenings which indicate a rapid conversion of portions of the superficial strata of the Rete Malpighii into horny masses contain masses of minute granules, the character of which, whether micrococci or not, cannot at present be definitely ascertained. Nor can the nature of similar granules be determined which are filling the cavities in the epidermis of that very early case that had been examined, viz., Case 1, that died after two days' illness.

Similar changes as in the Rete Malpighii have been noticed in the hair follicles, *i.e.*, distinct germination of the epithelium of the external root sheath, and occasionally also a few migrants amongst its cells; further, thickening of the internal root sheath (which evidently corresponds to the stratum lucidum of the epidermis), and also the presence of nuclei, or parts of nuclei, being the nuclei of the cells out of which this structure is being formed, and masses of granules.

Fenwick† found in three cases the Rete mucosum thickened, and containing numerous round cells with large nuclei; and further he mentions that the epithelium of sweat glands becomes thickened so as to fill the tube; it then becomes detached and removed from the basement membrane, which is thickened. In one of the cases the coiled tubes were loaded with coagulated blood; in another case the external layers of the cuticle were stained with blood in patches, and the ducts of the sweat glands were also reddened. As I have repeatedly mentioned, there was in many early cases germination of the epithelium in the coiled tubes as well as in the ducts, and likewise partial detachment and even breaking down of the lining epithelium; but I cannot quite see how these appearances are placed side by side with the desquamation of the epidermis, as is done by Fenwick. This author believes that inasmuch as the epithelium of the sweat glands becomes first thickened and then detached from the basement membrane, the changes in the sweat

* Quoted in Thomas's Article, l.c., p. 211.

† The Morbid States of the Stomach and Duodenum. 1868, p. 107.

glands are analogous to those of the epidermis. This opinion is, to my mind, based on a misconception of the nature of the desquamation of the epidermis. The difference between the two processes is very obvious. In the epidermis we find a very active new growth, and then a very rapid and copious horny transformation and subsequent detachment of the strata so changed; in the sweat glands, on the other hand, it is true we meet at nearly all stages of the disease, in some parts of the glands, a multiplication of the nuclei of the epithelial cells, and even an enlargement of these latter, so as to fill up the tube completely, but whether in consequence of active growth, or of swelling up due to the inflammatory exudation, I do not pretend to know, but then there is detachment of epithelium from the basement membrane and a total breaking down of the former. It seems to me that this detachment of the epithelium in some parts of the tube is in no way connected with or subsequent to the enlargement of the epithelium, for both occur side by side and both are caused by the inflammatory conditions. Why should the detachment of the epithelium from the basement membrane and the subsequent breaking up not be caused by an excessive exudation of fluid from the blood vessels, just in the same way as in other parts of the body excessive exudation of fluid produces a loosening and disintegration of epithelium, *e.g.*, that of the surface of mucous membranes in inflammation?

I cannot state with confidence the thickening of the membrana propria of sweat glands, which is mentioned by Fenwick in his cases.

Among the 20 cases only in one case (case 7, death after five days) have I observed blood more or less altered in sweat glands. In this case there were masses of blood in lymph-spaces which (blood) had escaped from ruptured blood vessels.

Thomas, l.c., says on p. 210, "Under the influence of a hæmorrhagic "diathesis, which may be superinduced by a severe scarlatinous affec- "tion, especially under otherwise unfavourable circumstances, exuda- "tions of blood often take place into the superficial layers of the skin " . . . . . hæmorrhages into the subcutaneous cellular tissue may also "occur."

If the changes of any part of the eruption are to be regarded as analogous with those of the epidermis, it is those of some of the hair follicles, in which we have seen not only very distinct signs of active germination of epithelium, but also copious formation of horny masses in form of what appears to be thickened internal root sheath.

I pass by without special comment the general inflammatory condition of the corium in the earlier stages, *i.e.*, enlarged papillæ, increased irrigation with fluid, viz., distended interfascicular lymph-spaces, distended blood vessels, and the infiltration with lymphoid cells. With reference to these latter I have specially to mention their distribution, they being chiefly contained in the tissue around blood vessels—veins and capillaries—hair follicles, and in some cases also around sweat glands.

Of greater importance is the change we have observed in the walls of blood vessels; this consists, in (*a*), a distinct germination of the nuclei of the endothelium, and (*b*) of the nuclei of the muscle-cells in the coat of arteries. Around some of the blood vessels may be found numerous oblong nuclei of the general character of endothelial nuclei, and hence it is probable that a multiplication takes place also of the nuclei of the endothelium of perivascular lymphatics.

III.—Microscopic Examination of Kidney.

(A.)—*In the above Cases.*

Case 1.—The examination of this case, which, as may be remembered, was the earliest of the series, proved of great importance, as the tissue of the kidney presented already certain important changes. These changes are limited chiefly to the cortical substance. Near the capsule many Malpighian capsules are met with which are filled with granular matter and blood; the same material is contained also in the convoluted tubes. Many of the glomeruli show a much greater number of nuclei than in the normal condition. On more careful examination it is found that the increase of nuclei is due to a germination of the nuclei of the epithelial cells attached to the external surface of the capillaries, and most probably also to a germination of the nuclei of the wall of the capillary vessel itself. The epithelium lining Bowman's capsule is in some Malpighian corpuscles composed of large, almost columnar, opaque cells, the nuclei of which are in a state of division or already divided. The most internal part of the cortex, *i.e.*, that bordering on the basis of the pyramids, contains few Malpighian corpuscles, in which little only of the glomerulus is to be detected (see Figs. XI.), the interior space of the Malpighian corpuscle being much smaller in size, owing to the presence of concentric more or less distinctly fibrous layers, which apparently belong to Bowman's capsule; in them may be recognised round or oblong nuclei. I have followed these changes in many Malpighian corpuscles, and I have come to the conclusion that the nuclei of these fibrous more or less concentric layers are the nuclei of the epithelial cells as well as of the capsule, which cells have apparently undergone fibrous degeneration. The material in question does not look everywhere like fibrous tissue, for in some instances it presents more the appearance of a homogeneous substance which is indistinctly striated. In some Malpighian corpuscles this degeneration shows itself as a thickening of the capsule, whence the degeneration seems to spread on to the glomerulus, attacking first one lobule and then another. The degenerated parts become fused so as to form one continuous mass. During all this time the nuclei of the glomerulus itself become very much increased in number, many of them showing distinct signs of division; the wall of capillaries swells up and the lumen gradually disappears. In a further advanced stage nothing is left of them except a few opaque masses containing groups of nuclei. The amount of fibrous tissue containing a few nuclei around the so changed Malpighian corpuscle is considerable. It is very peculiar that these changes should be found on Malpighian corpuscles situated in the most internal portion of the cortex. I may mention on this occasion the presence of groups of lymph-cells, with one or two or three small nuclei in the tissue around the large arterial trunks penetrating between cortex and pyramids.

[There are bundles of unstriped muscle fibres of considerable thickness in the tissue around the arterial trunks, and also in the tissue of pelvis. The nuclei of this muscular tissue show the same proliferation as in the arteries.]

Another important change is to be found in the cortical arteries, the larger branches as well as minute arterioles. This change consists in a very active division of the nuclei of the unstriped muscle fibres; in many instances the characteristic staff-shaped nuclei are replaced by a linear series of two, three, four, or more small nuclei. There can be no doubt that these result from the division of the original staff-shaped nuclei. In many instances, especially in the small arterioles of the cortex, the muscular coat is in consequence of these changes thicker than in the normal condition. Besides the germination of the nuclei of

the muscle fibres, also the nuclei of the endothelium of the arterioles undergo multiplication. To these facts must be ascribed the peculiar appearance that presents itself at the peduncle of some Malpighian corpuscles, for there we find a very conspicuous number of nuclei, which can be still recognised as having resulted from division both of the longitudinal nuclei of the endothelium and the transverse nuclei of the muscular fibres. Another noteworthy appearance in connexion with this change in the afferent and efferent arterioles is the great abundance of nuclei in the epithelial lining of what appears to be an ascending tube of Henle, and what is still more peculiar is that, this increase of nuclei is generally to be observed only on that part of the wall of the tube which is in contact with, or nearest to, the afferent arteriole. I have represented these changes in Fig. VI., accurately copied from a preparation.

Besides the changes enumerated, there is some other change to be noticed on afferent arterioles, either close to the Malpighian corpuscle, or after having already penetrated through the capsule, consisting in the swelling up of a portion of the intima, or a greater or smaller part of the circumference of the arteriole into a hyaline, highly refractive material, resembling what is described by some pathologists as glassy hyaline degeneration; it does not yield amyloid reaction. (I have represented these appearances in Fig. VII.)

It becomes thus probable that the degenerative changes of the Malpighian corpuscles above described are analogous to these changes of the arterioles. The degeneration of Malpighian corpuscles is not of the nature of amyloid degeneration as has been already evident from our description. Iodine, as well as methylaniline, which has come into use only recently for demonstrating amyloid substances, gives no reaction. (We shall learn more about the nature of this degenerative process in some of the following cases, where it is more easily followed.)

With reference to the urinary tubes, there are certain changes to be observed; they are: cloudy swelling of the epithelium of a few convoluted tubes, which leads to disintegration of the epithelial cells; in others the nuclei are double in some of the epithelial cells.

In the cortical as well as in the medullary portion of the ascending tubes of Henle, the epithelial lining is in some instances detached from the membrana propria, and in addition to this, in the cortex, breaking up into small nuclear fragments. There are a few hyaline cylinders to be met with in Henle's loops.

Some of the large collecting tubes of the pyramids are collapsed. Their epithelial lining is shrunk into an opaque mass; in others the epithelial lining is altogether gone.

In this, as well as in most other kidneys, I found a considerable quantity of yellowish brown pigment in the form of smaller or larger granules or irregular lumps contained in the epithelial lining of the descending limb of Henle's loops just as they emerge from the cortex, and it may be traced in them for a little distance into pyramids. The extent in which pigment is found in the epithelium of these tubes varies in different kidneys, but at all events it seems to form as a part of the normal structure of the kidney. (This pigment will be mentioned hereafter only where it occurs in large quantities.)

Case 2.—The changes in this case are similar to those in the preceding one, only not so intensive, as there are no Malpighian corpuscles which have become degenerated in the manner above mentioned. In one instance only have I seen a Malpighian corpuscle near the pyramids which showed degeneration of the glomerulus.

Many Malpighian corpuscles, however, show an increase of the nuclei

of the glomerulus: signs of division of nuclei, and even nuclei already divided are not rare. Also the swelling of the epithelial cells (and division of their nuclei) of the capsule near the neck of the convoluted tube may be met with. The cavity of some Malpighian corpuscles contains granular matter and what appears to be remnants of blood corpuscles. Granular material is also contained in the convoluted tubes. The germination of the nuclei of the muscular coat, and also of the endothelium of arterioles, as described in the former case, may be observed also here; and likewise the great increase of nuclei of the epithelial lining of that part of an ascending Henle's tube which is in contact with the afferent arteriole next the Malpighian corpuscle. In some glomeruli next the pyramids the wall of capillary vessels is thickened and swollen. In the close vicinity of a large arterial trunks I have found a Malpighian corpuscle, around which there is a collection of lymphoid cells, with one, two, or three nuclei.

The epithelial lining in a few convoluted tubes shows cloudy swelling; in some epithelial cells the nucleus is very small, faintly stained as if disappearing—or perhaps in the course of formation—in others the nucleus is double. In a few convoluted tubes the swollen epithelial lining is disintegrating and breaking up into granular fragments. Many of the ascending Henle's tubes in the cortex show their epithelium detached and disintegrating.

The collecting tubes of the pyramidal portion show in some instances their epithelial lining detached and breaking up into small nuclear fragments, or even entirely gone. In the latter case the membrana propria is seen to contain large nuclei, either isolated or in groups of two or three, and the impression is produced as if it were composed of endothelial plates. Near the papilla cylindrical or irregular masses may be found composed of coarsely granular amorphous or globous matter, which in unstained preparations have the same shining aspect as amyloid; they do not show, however, the chemical reactions characteristic of amyloid; and assume a more or less deep purple-violet colour in hæmatoxylin. They appear to be contained in tubes—apparently collecting tubes—which are distended and blocked up by them occasionally to such an extent that the surrounding tissue is more or less degenerated. The material in question is soluble in dilute hydrochloric acid without, however, effervescing; it is therefore not carbonate of lime but probably some other salt of lime.

There are also a few hyaline cylinders in collecting tubes of the pyramids.

In the tissue of the calices are found numerous mono-nuclear lymph-corpuscles, some of which are conspicuous by their size, their deep staining, and their coarse granulation.

Much pigment is present in the first part of the descending limbs of Henle's loops.

The larger blood vessels are filled with blood. Numerous colourless blood corpuscles and also a little fibrin in veins.

Case 3.—The glomeruli show in most instances an increase of the number of nuclei; in some the wall of the capillary vessels appears swollen, more or less degenerated into a granular or slightly fibrillar mass. The internal portion of the cortex contains Malpighian corpuscles in which degeneration has advanced considerably on the capsule as well as the glomerulus. The cavity of many Malpighian corpuscles contains granular matter, disintegrated cells, and what appear to be the remains of blood discs. In one instance the glomerulus was quite collapsed and in its stead a heap of nuclei was to be found, whereas

the cavity of Bowman's capsule was filled with a uniformly and finely granular substance slightly stained in hæmatoxylin in which were embedded a few lymph-corpuscles. At a peripheral point in the same Malpighian corpuscle was found a lump of the same globular matter (lime) of deep purple colour as has been mentioned to occur in tubes of the papilla in the previous case. In the smaller as well as in the larger arteries, there is the same germination of the nuclei of the muscular tissue, in the former also of the nuclei of the endothelium. Likewise we meet with the increased number of nuclei of epithelial cells in that part at the ascending Henle's tube next an afferent arteriole, as has been mentioned in the preceding cases. The hyaline swelling of portions of the intima of afferent arterioles before and after having penetrated Bowman's capsule is conspicuous. In the connective tissue surrounding the large vascular trunks, penetrating between cortex and pyramids, may be noticed numerous lymph-cells, amounting at some places to considerable collections. They extend into the cortex as well as (although to a smaller extent) into the pyramids for a short distance ; in the former they are situated between the convoluted tubes and around the adjacent Malpighian corpuscles, in the latter they extend between the straight blood vessels and urinary tubes.

The epithelium of a few convoluted tubes shows cloudy swelling ; in some the epithelium is filled with small vacuoles or even disintegrating into granular fragments ; the latter condition may be met with chiefly in the first part of the convoluted tubes, *i.e.*, that next Bowman's capsule. In many of the swollen epithelial cells of convoluted tubes a germination of nuclei may be noticed. Some of the tubes of Henle and also some of the collecting tubes contain cylinders composed of hyaline or more or less granular material.

The same irregular masses of granular or amorphous globous (lime) matter observed in the papillary part of the preceding case may be found in this case. Here also they stain deeply in hæmatoxylin.

The larger blood vessels are filled with blood ; the veins contain numerous colourless blood corpuscles and fibrinous matter.

On the naked-eye examination of the kidney of this case no trace is to be perceived of the extensive changes described in the foregoing.

Case 4.—Many Malpighian corpuscles contain granular matter and remains of blood. The same is the case in the distended convoluted tubes. The epithelium of some of the latter is either detached from the membrana propria or is in the state of cloudy swelling, or disintegrating into fragments of granular matter.

The germination of the nuclei of the endothelium, but chiefly of those of the muscular coat of arterioles, is very distinct, and especially remarkable is the number of nuclei (nuclei of muscle fibres and of endothelium) of arterioles just at the point of entering Bowman's capsule.

Besides these changes also the hyaline swelling of portions of the intima may be observed in some arterioles. The Malpighian corpuscles whose glomerulus is in a state of fibrous degeneration are very scarce, and then they are near the periphery and of an "embryonic character."

This last expression requires some explanation. In kidneys of young subjects, such as those whose bodies were the source of our anatomical material, there are found in the peripheral part of the cortex small Malpighian corpuscles (their number is always limited, and is smaller in older children than in infants), which differ from ordinary Malpighian corpuscles in the following respects : (*a*) they are very small and only few or no distinct

capillary vessels are to be observed in them, (*b*) the glomerulus is covered with a continuous layer of polyhedral epithelial cells. It is evident that these Malpighian corpuscles are not yet fully developed, but possess still an embryonic character. I have observed in this and in other cases of scarlatina that the "embryonic" Malpighian corpuscles are very favourite subjects of fibrous degeneration.

Many glomeruli show an increased number of nuclei, and the wall of the capillary vessels is opaque and thickened.

The epithelium of ascending tubes of Henle in the periphery of cortex is detached from the membrana propria, or is even breaking up into small elements.

Arteries and veins are full of blood, also a slight amount of fibrin may be noticed in them.

In veins of pyramidal portion numerous colourless blood corpuscles.

Whenever we do not make any special mention of the condition of the intertubular capillary blood vessels of the cortex it will be understood that they are not visible in our hardened specimens.

Arteries as well as veins contain a few cylindrical or spherical more or less homogeneous lumps of a glistening aspect; they look very much like soft gelatinous casts of capillary vessels. They possess, it is true, the peculiar glistening aspect of fat, but they do not show any chemical reaction characteristic for fat; they are most probably derivations of blood.

Small accumulations of lymph-corpuscles may be met with in the adventitia of a few interlobular arteries as well as veins.

Case 5.—This case may serve as a further illustration of the fact that although on superficial examination there is little change to be noticed, the careful examination of well-stained (hæmatoxylin) sections reveals considerable progress in the vascular alterations. These are as follows: (*a*) in many glomeruli the number of nuclei increased; (*b*) arterioles show the hyaline swelling of intima, *i.e.*, blocks of colloid-looking matter in this latter, in a few cases leading up to total obliteration and degeneration of the vessel; the swollen-up wall looks then more like a fibrous material. This hyaline swelling is present also in a greater or smaller number of capillaries of glomeruli, their wall containing an oblong or spherical block of that hyaline substance. In glomeruli of this kind the wall of the capillaries in general is of a granular and opaque aspect.

Near the capsule of the kidney are a few "embryonic" Malpighian corpuscles, in one or the other portion of which fibrous degeneration has already commenced.

The arterioles in general, even where their lumen is not to be seen, are recognisable by the great number of nuclei of the endothelium, but chiefly of the muscular coat. The germination of nuclei of the epithelium of that portion of Henle's tube next an afferent arteriole is also here conspicuous.

The connective tissue, in which are embedded the large vessels, contains small collections of lymph-corpuscles.

Some Malpighian corpuscles contain granular matter and blood, so also the convoluted tubes near the capsule of the kidney, and to a smaller extent the convoluted tubes in the inner part of cortex. In a few of the latter the epithelium shows cloudy swelling, fatty degeneration, and even disintegration.

In other convoluted tubes the nuclei of epithelial cells are proliferating. The epithelium of ascending Henle's tubes near the capsule

of the kidney is detached from the membrana propria, and even breaking down into small nuclear granular elements.

A similar condition, though to a lesser degree, may be observed in some of the ascending branches of Henle's loops in the pyramids, and also in some of the large collecting tubes of the latter region.

Considerable amount of pigment in the first part of descending branch of Henle's loops.

There are a few hyaline cylinders in tubes of cortex as well as pyramids.

Case 6.—This case is *in every respect* similar to the preceding one, especially with reference to the changes in arterioles and glomeruli. The germination of nuclei of muscular coat is distinctly perceptible, also in the large arterial trunks; in the latter the muscular coat is markedly thickened. Thus I find in a branch of the renal artery filled with blood, the whole diameter of which branch (including the adventitia) amounts to very little over 0·7 mm., the muscular coat at some places measuring over 0·2 mm. In the same branch there was present at one point an internal longitudinal muscular layer of about 0·05 mm. thickness.

Also the urinary tubes show the same changes as in the preceding case. Much granular matter and fat droplets in the convoluted tubes. There is infiltration with lymph corpuscles of the connective tissue of calices, extending into the connective tissue around the interlobular vessels, and hence between the urinary tubes and Malpighian corpuscles of the adjoining parts.

In the urinary tubes of the basis of pyramids a few hyaline cylinders.

Case 7.—The changes of this case are similar to those of case 5, with the following additional features: (*a*) there are a few Malpighian corpuscles near the capsule of the kidney (which is much thickened, and which contains just at this point a few bundles of unstriped muscles) filled with a very finely and uniformly granular material which had stained with hæmatoxylin; in it were included a few lymph-corpuscles; (*b*) between tubes of cortex a few of those amorphous (lime) masses stained very deeply in hæmatoxylin; (*c*) the epithelium of some urinary tubes of cortex, collecting tubes, and chiefly Henle's ascending tubes, is breaking up into small fragments. The epithelium of many convoluted tubes is also disintegrating. There is considerable amount of pigment.

[The preparations of this case have not stained well with hæmatoxylin, the tissue assuming a uniform dirty violet-brown colour, although the staining fluid itself was of the usual quality.]

Case 8.—As far as the amount of change is concerned, the kidney of this case is nearly as early as any that I have examined; the changes are as follows: (*a*) thickening of minute arterioles due to germination of nuclei of endothelium, but chiefly of those of the muscular coat: the great number of nuclei is especially conspicuous in the arterioles entering Bowman's capsule. (*b*) A few embryonic Malpighian corpuscles in the state of degeneration. I have seen a Malpighian corpuscle near the internal margin of cortex, the glomerulus of which was almost completely transformed into a group of swollen hyaline, or very faintly fibrillar lumps, and between them a few nuclei; the tissue around this Malpighian corpuscle was infiltrated with lymph-corpuscles, extending also between the urinary tubes of the immediate vicinity. (*c*) In the adventitia of some of the large vascular trunks small collection of lymph-corpuscles may be noticed. (*d*) The nuclei of many glomeruli increased in numbers. (*e*) The Malpighian corpuscles contain granular matter and

remnants of blood (viz., decolourized blood discs); the same material is contained in the convoluted tubes near the base of pyramids, *i.e.* the first section of the urinary tubes; epithelium of some convoluted tubes swollen; numerous cells possess two nuclei; in some convoluted tubes the epithelium appears to become disintegrated. (*f*) Epithelium in many ascending branches of Henle's loops, and also in collecting tubes of pyramids, detached from membrana propria.

There are a few hyaline cylinders in tubes of pyramids. Blood vessels next the capsule in some parts distended and filled with blood. Large veins as well as arteries filled with blood, granular matter, and fibrin.

Bundles of unstriped muscle fibres may be found in the tissue surrounding the larger vascular trunks. Also in this kidney I found a large branch of the renal artery that possesses at one part a longitudinal bundle of unstriped muscle fibres internal to the circular muscular coat.

Some veins contain numerous colourless blood corpuscles.

Case 9.—A few obliterated Malpighian corpuscles. Many Malpighian corpuscles show abundance of nuclei. In some the capillary vessels are very opaque. Slight infiltration with lymph-cells of the tissue around large vascular trunks, which extends also on the tissue around some interlobular arteries and Malpighian corpuscles. Granular disintegration of epithelium of some convoluted tubes. (The epithelial cells lining the first part of convoluted tubes, and also that of the ascending branches of Henle's tubes of cortex, show very well marked the well-known rods first described by Heidenhain.)

The blood vessels of the fresh kidney had been injected with ¾ per cent. saline solution, then with Berlin-blue, and hardened in a mixture of chromic acid and spirit.

In many urinary tubes of the cortex the epithelium appears loose or entirely detached from the membrana propria. Near the capsule of the kidney the epithelium of urinary tubes (convoluted tubes and ascending Henle's tubes) is breaking up into small nuclear granular fragments.

In the pyramids the epithelium of many ascending branches of Henle's loops, and also of collecting tubes, is detached from the membrana propria. In the latter it may be found even breaking up into the individual cells.

Many Malpighian corpuscles of the periphery of cortex contain granular matter and what appears as decolourised blood corpuscles, or parts of them. There are a few hyaline or finely granular pigmented cylinders in tubes of cortex.

The kidney was swollen and hyperæmic. In some of the calices was contained an amorphous brittle mass which yielded no reaction with acids, ether, or alcohol.

Case 10.—The following are the predominant changes: (*a.*) Increase of nuclei in many glomeruli. The wall of capillary vessels appears at the same time much thickened, or replaced by opaque, granular, or slightly fibrillar matter. Of this last substance, *i.e.*, fibrillar substance, I am not quite certain that it is not between the capillary vessels. There are also Malpighian corpuscles that have become quite degenerated. The germination of nuclei of muscle fibres of afferent arterioles is very marked just before this latter enters the Malpighian corpuscle. At the same place is also conspicuous the number of nuclei of the epithelium of the Henle's tube lying close to the arteriole. (*b.*) There are numerous arteries in the different parts of cortex, especially those next the large trunks, the intima of which has over a larger or smaller

area, swollen up into a homogeneous glistening substance, which in some places is so large that it narrows the lumen of the vessel to a considerable extent. I have seen an arteriole where this thickening is present only on one side of the vessel, and it is of so high a degree that the lumen has become excentrical and reduced to a minimum size. In arterioles in which the intima has changed only slightly, the nuclei of the muscular coat are seen in a state of division; where, however, the intima has considerably swollen up the muscular coat seems to have given way altogether. Some of the larger arterial trunks and also some of the interlobular arteries contain lymph-corpuscles in their adventitia.

At some places the connective-tissue of calices is much infiltrated with lymph-corpuscles, which infiltration extends on to the tissue around the large veins.

Many Malpighian corpuscles contain granular matter and remnants of blood. There is a considerable amount of granular matter in convoluted tubes, many of which are changed; either their epithelium is slightly swollen and the nuclei of the latter abnormally numerous—in some of the swollen epithelial cells are contained as many as seven or eight nuclei—or the epithelial cells are full of minute vacuoles and disintegrating into granular fragments, the nuclei having previously disappeared: or, finally, the swollen epithelial cells are filled with fat droplets.

A few hyaline cylinders, including coarse granules, may be found in Henle's tubes of cortex. Also a few of those deeply stained amorphous or globose (lime) masses are found in the cortex. There are a few hyaline cylinders in the pyramids, some including yellowish granules in their central part. The epithelium of ascending branches of Henle's loops, and also of collecting tubes of pyramids, is in many instances detached from the membrana propria, and breaking up into small elements; in the former some parts of the epithelial cells show the rod-like structures of Heidenhain with great distinctness. [This is to be noticed also in many of the other cases.] In the large collecting tubes of the papillary portion the lining epithelial cells are very transparent, some of them becoming disintegrated.

The large blood vessels, veins as well as arteries, are filled with blood.

Case 11.—There are a few large arterial trunks the tissue around which is more or less filled with lymph-corpuscles, chiefly small cells containing two or three small nuclei. These cells extend between the convoluted tubes; some of the latter are quite filled with them. Some Malpighian corpuscles contain granular matter and what appears to be remnants of blood. The same is contained in convoluted tubes, especially in the periphery of cortex.

There are a few places at the basis of pyramids where lymph-corpuscles are found accumulated in the tissue around some of the large vascular trunks.

Blood vessels next the capsule filled with blood. The blood vessels of the basis of pyramids distended, and contain more or less altered blood. There are a few hyaline cylinders in tubes of the last-named region. The epithelium of the collecting tubes of pyramids is normal.

Case 12.—Many glomeruli show an increased number of nuclei; some of these appear imbedded in granular opaque cell-substance, the wall of the capillary vessels being at the same time less distinct. From Malpighian corpuscles of this condition there are intermediate conditions to Malpighian corpuscles which show no distinct capillary vessels, but which are occupied by hyaline or slightly fibrillar masses in and between which nuclei are still to be recognised. In Fig. XII. is repre-

sented a Malpighian corpuscle which shows a thickened degenerated capsule, a part of the glomerulus is converted into a hyaline or slightly fibrillar material; other parts are represented by nuclear opaque cell-masses. From the examination of this and other cases, I have become convinced that the obliteration of Malpighian corpuscles, *i.e.*, their conversion into fibrous masses, starts with an increase of the nuclei of the glomerulus, is then followed by the appearance of large granular or hyaline masses, including those nuclei, the capillary vessels at the same time becoming less distinct; after this the capillary vessels become altogether invisible, whereas those masses gradually change into a more or less fibrillar structure, in which nuclei remain visible for some time. The capsule of the Malpighian corpuscle has become thickened during this time—generally this is already perceptible at the outset—its layers swell up first into a hyaline mass in which the nuclei of the original epithelium may be recognised, and gradually become converted into a fibrillar substance.

In the case we have now under consideration there are Malpighian corpuscles next the large vascular trunks, as well as some of the peripheral embryonic Malpighian corpuscles undergoing the obliterative change. Other important changes are to be noticed on the small and medium sized arterioles, their wall being thickened owing to the germination of the nuclei of the muscular tissue; in a considerable number of arterioles the intima is found to be swollen and changed into the hyaline glassy substance, which in some places is so voluminous that the lumen of the vessel is nearly or entirely obliterated. In a later stage the swollen intima appears to change into an indistinctly fibrous substance quite analogous to that into which the glomeruli degenerate. It is interesting to observe that many arterioles next the basis of pyramids show the last-named obliterative changes.

Slight infiltration with lymph-cells may be noticed in the tissue around the large vascular trunks. In one instance I have seen also in the cortex infiltration with lymph-cells of the tissue around a Malpighian corpuscle and between the nearest urinary tubes; the epithelium as well as the lumen of some of these were crowded with them.

There are a few hyaline cylinders in tubes of cortex as well as pyramids, and also in a few instances there were seen in the cortex those deeply stained irregular lime masses.

The epithelium of convoluted tubes shows in a few instances granular disintegration.

The epithelium of ascending branches of Henle's loops and also of some collecting tubes in the pyramids is detached from the membrana propria, and in some places it is breaking up into small elements.

Large blood vessels filled with blood. The vasa recta of the pyramids are distended.

Case 13.—This case shows very little change as compared with the preceding one. It is chiefly: (*a.*) Slight germination of nuclei of muscular coat of arterioles and consequently thickening of the latter. A few peripheral Malpighian corpuscles showing obliterative changes. (*b.*) Infiltration with lymph-cells of the tissue around the large vascular trunks. (*c.*) A small amount of granular matter and blood is contained in some of the Malpighian corpuscles, and the same is seen in convoluted tubes near the pyramids. Blood is contained in some of the large lymphatics of the tissue of calices. In one place there was effusion of blood, in which pigment has already made its appearance, so that it is probably of some duration. The large blood vessels are full of blood.

The urinary tubes in the same condition as in the preceding case, with the addition that some of the large ducts of the papillary part are collapsed or their epithelium quite gone.

Case 14.—The following changes are to be noticed in this case: (*a.*) Thickening of muscular coat of small arteries, swelling up of parts of intima in many arterioles. (*b.*) Thickening of capsule of many peripheral Malpighian corpuscles, in some the glomerulus shows obliterative changes. There are glomeruli in which an increase of nuclei may be noticed, and in several such instances have I found peculiar deeply-stained huge masses, apparently *in* capillary vessels, which masses present the appearances of a well-defined granular lobed nucleus in the act of dividing into two portions connected by a longer or shorter neck, each portion presenting a number of constrictions. (*c.*) Most of the peripheral Malpighian corpuscles which do not show obliterative changes of glomeruli contain granular matter and chiefly masses of blood corpuscles (decolourised). The same material is contained in convoluted tubes, especially in those near the capsule of kidneys.

I must call special attention to this fact (mentioned also in several previous cases), because in the notes furnished to me from the hospital mention was made that the urine in this case had ceased to contain albumen three days before death. In cases 5 and 12 I find in the notes that the urine contained no albumen. It would appear that although Malpighian corpuscles and convoluted tubes contain granular matter—most probably coagulated albuminous matter—and blood, still the urine passed from the kidney did not contain albumen perceptible by the ordinary test. In all these cases the tubes of the pyramids did not show any traces of that albuminous or bloody exudation.

The epithelium of urinary tubes in general shows little change. A few ascending tubes of Henle show detached and disintegrating epithelium. A few tubes of pyramids contain hyaline cylinders. Some of the large collecting tubes of papillary portion appear collapsed, their epithelium shrunk and opaque; in others the epithelium is detached or altogether gone, or it is broken for some distance and the tube filled with granular matter in which a number of different sized very pale and transparent circular bodies may be recognised, probably the well-known drop-like masses which are seen to come out from epithelial structures under very various conditions.

The membrana propria of some large collecting tubes, in which the epithelium has become detached, is opaque and granular, and shows very distinctly membranous processes projecting into the epithelium.

Large blood vessels are filled with blood; the same also in all the blood vessels of pyramids.

I found the deeply-stained globular (lime) masses in the cortex also of this case.

Case 15.—The changes in the kidney of this case are very slight; the following may be observed:—The vessels of the periphery of cortex are very much distended and filled with blood. In some instances the urinary tubes near the capsule appear very much compressed by the distended vessels around. There are arterioles, not in numerous instances though, which show the increase in number of the muscular nuclei, others the homogeneous swelling of intima, and even total obliteration. Likewise there are Malpighian corpuscles, chiefly embryonic ones near the capsule of kidney, the glomeruli of which are in different degrees of degeneration, as mentioned repeatedly before. In the adventitia of some interlobular arteries are contained a few lymph-cells; this is more distinct in connexion with the large vascular trunks,

whence the infiltration with lymph cells extends also on the vasa recta of the basis of the pyramids. The larger veins contain numerous colourless blood corpuscles. Some Malpighian corpuscles and the first part of convoluted tubes contains granular matter; in the latter the epithelium appears opaque and slightly swollen and breaking up into small granular fragments. In a few ascending tubes of Henle (of the cortex) the epithelium is detached from the membrana propria and is breaking up into small elements.

In many collecting tubes of the papillary part the epithelium is also detached from the membrana propria, and is either shrunk into an opaque nuclear mass or altogether gone. The adventitia of the large vascular trunks, especially arteries, contains blood, or appears distinctly stained with blood pigment.

Case 16.—This is the brother of the previous case, whom he survived by one day. It is the first marked case of interstitial nephritis. The kidney exhibits the same features, with the addition that the infiltration with lymph cells in the adventitia of the roots of the interlobular vessels, especially veins, is considerable, *i.e.*, has more advanced than in case 15. Fig. XVI. represents a slight degree of infiltration with lymph cells; as is shown in the drawing they extend already between urinary tubes the epithelium of which is more or less crowded with, and disintegrated by, them; but they are present also along the vasa recta of the basis of the pyramids. It is to be observed, especially in connexion with the latter fact, that thickening is to be noticed in the coats of arterioles, near the infiltration.

Infiltration with lymph-cells may be observed also in parts higher up the cortex, where Malpighian corpuscles, more or less changed, appear to be the centre of the infiltration, from which the lymph-corpuscles extend around and between the urinary tubes of the vicinity. In all cases, however, the medullary rays are free from infiltration. With regard to the lymph-corpuscles of the infiltration, all different kinds may be observed with reference to size of the cell and size and number of nuclei. There are ordinary small colourless corpuscles with two or three small nuclei, then corpuscles with one round deeply-stained nucleus, then there are larger cells with one or two large transparent nuclei.

The epithelium of the first portion of the convoluted tubes is opaque and slightly swollen, in some places it appears to be breaking up into granular particles; some of the large collecting tubes of papillary part contain an opaque, shrunk, and detached epithelium. There are a few hyaline cylinders in tubes of medulla.

The adventitia of some large arterial trunks contains blood.

Case 17.—In the microscopical examination of this case numbers of small foci of interstitial nephritis are found in different parts of the cortex. The intertubular cell-infiltration is seen to be more or less distributed in such a manner that either Malpighian corpuscles, or occasionally also arterioles, or both, appear to be the centre around which the lymph cells are chiefly crowded, and whence they spread between the urinary tubes of the surrounding parts; that is to say, the interstitial nephritis is chiefly limited to the part contained between the medullary rays. The urinary tubes of the infiltrated parts show the changes usually observed in interstitial nephritis, viz., (*a.*) crowding of epithelium and lumen of tubes with lymph-cells; the denser the infiltration the more distinct is this, and the further advanced also are the disintegrative changes of the epithelium; (*b.*) hyaline cylinders in tubes; (*c.*) cylinders composed of exudation cells and of disintegrated

epithelial cells more or less swollen and hyaline; in the latter case the tube is much distended and the cylinder is composed of distinct hyaline blocks still showing traces of nuclei.

With reference to the lymph-corpuscles of the infiltrated parts, there is nothing to be added to what has been said in the preceding case.

Where the lymph-cells of the infiltrated parts have become removed in the course of preparing the section, it is seen that they are embedded in a meshwork of opaque or granular membranous structures, which network is the more distinct the less there is left of the epithelium of the urinary tubes, so that it is probable that that membranous matrix includes, besides pre-existing intertubular connective tissue, the membranes of the original urinary tubes. This is borne out by carefully examining those places where the exudation-cells gradually replace the epithelium in the urinary tubes.

The Malpighian corpuscles which are found in the infiltrated parts, *i.e.*, in the foci of interstitial nephritis, are in different stages of fibrous degeneration, as described in previous cases (*see* also Fig. XIII., which is taken from a specimen of this case).

So it is also with the arteries of and near those foci; they show thickening of muscular wall, in some instances swelling of intima or even total degeneration of their walls. The greatest number of degenerated Malpighian corpuscles and arterioles may be found in that part of cortex which is nearest to the pyramids, *i.e.*, in the vicinity of the large vascular trunks; and in this part are also the most numerous foci of interstitial nephritis.

From this and from the facts mentioned in previous cases we shall draw the inference that the degenerative changes of Malpighian corpuscles and arteries is *not subsequent* to the interstitial nephritis. To this point we intend to return more fully when summarizing the results of our examination of the kidney of the different cases.

The epithelium of some convoluted tubes is swollen, in others it shows granular disintegration. In cortical ascending tubes of Henle the epithelium is detached and breaking up into isolated nuclear elements. The epithelium of collecting tubes and ascending branches of Henle's loops of pyramids is more or less detached from the membrana propria; in some large ducts of papillary part the epithelium is altogether gone.

The blood vessels of pyramids distended.

There is a considerable amount of yellowish-brown pigment granules contained in the epithelium of first portion of descending branches of Henle's loops.

In one instance a distended urinary tube of cortex contained a huge homogeneous opaque block, including brownish pigment granules.

In a few instances there are the deeply-stained amorphous masses (lime) in distended urinary tubes of cortex.

It is remarkable that the urine did not contain albumen.

Case 18.—The interstitial nephritis, as observed under the microscope, is very considerable in this case; it is not noticed by the unaided eye except on stained sections, in which the infiltrated portions, *i.e.*, the interstitial inflammation, may be perceived as thin streaks or small patches of deeply-stained tissue in the different parts of the cortex. The greatest amount of infiltration is here also chiefly in parts next the roots of the interlobular arteries, but there are also other parts of the cortex, including the most peripheral portion, in which interstitial change has set in. Next the capsule of the kidney the intertubular tissue is filled with lymph-cells over considerable areas.

As may be expected there are many Malpighian corpuscles in different stages of degeneration; those that have undergone complete

obliteration are found chiefly near the roots of the interlobular arteries. In the very periphery of the cortex the greater number of glomeruli appear to be impermeable, their nuclei being much increased and the walls of the capillary vessels indistinct, owing to the presence of opaque granular swollen cell-masses.

In connexion with the foci of interstitial nephritis there are certain facts to be mentioned which I have little doubt are likely to throw some light on the nature of the interstitial nephritis. These facts consist in nothing less than embolisms of arteries. In Figs. XIV. and XV. I have selected two of the most characteristic examples; I need hardly say that I have copied these drawings from the preparations with the greatest possible accuracy.

As is shown in one of them, there is a middle sized interlobular artery, which at one place, just where a lateral branch is coming off (cut away obliquely in the preparation), is distended and blocked up by an embolus of considerable size. In the other figure an embolus is shown in an afferent arteriole of a Malpighian corpuscle, just at the point of penetrating Bowman's capsule. Similar "riding" emboli in afferent arterioles and at the same point are present in connexion with many Malpighian corpuscles near the infiltrated peripheral parts of cortex.

We will first describe the nature of the embolus; it consists of different blocks of an apparently amorphous material, including a few cells and nuclei more or less changed. Under a very high power these blocks appear to be granular; they stain slightly with hæmatoxylin and are to all appearance of a fibrinous nature; this is in a great measure supported by the fact that they include cellular structures. In Fig. XV. the lower portion of the artery, *i.e.*, that nearest to the pyramids, contains blood; the upper is more or less empty; at some distance from the embolus it contains numerous lymph-corpuscles. The tissue all round is very intensely infiltrated, and this is more or less also the case in Fig. XIV., *i.e.*, in connexion with the emboli of the afferent arterioles.

The nature of the infiltration or interstitial nephritis is, I think, in no way incompatible with the assumption that it is caused by the embolism of interlobular arteries and their branches, for it quite corresponds to Cohnheim's scheme of inflammation subsequent to embolism of terminal arteries (the arteries of the cortex being terminal arteries par excellence.)

But why should not the embolism of arteries be also the cause of the degenerative process of afferent arterioles and Malpighian corpuscles, as described in this and previous cases? That those obliterative changes are to be observed oftener on the arterioles and Malpighian corpuscles nearest the root of the interlobular arteries, *i.e.*, nearest the large vascular trunks and on the "embryonic" Malpighian corpuscles of the periphery of cortex, seems to me to be much in favour of that assumption; for is it not likely that those minute arterioles which are nearest their large trunks should sooner fall victims to the embolic process than others which are further away? But perhaps there are other special circumstances, hitherto unknown, which determine the greater prevalence of obliterative changes in the last-named locality. The obliteration of embryonic Malpighian corpuscles, however, seems to me to be not incompatible with the theory of embolism, the afferent arteriole of an embryonic Malpighian corpuscle being evidently a vessel out of which there is no exit, or only a very imperfect one, considering that the capillaries of the corresponding glomerulus are only imperfectly developed, or, as in some cases, only very rudimentary.

Now, supposing there are masses circulating in the blood which may

still pass through arterioles and capillaries of well-developed Malpighian corpuscles, is it not possible that they will be arrested in the embryonic glomeruli? And why should there not be masses circulating in the blood which may give rise to the formation of emboli? Are not extensive inflammatory processes going on in the skin, in the throat, and in lymphatic glands, the microscopical characters of which we shall have occasion to discuss hereafter, and in consequence of which changes masses of formed material are carried away from the seat of these inflammations and brought into the circulating blood, which on account of its own changes may be only too favourable to the formation of emboli or thrombi? Thus we shall see afterwards that in lymphatic glands and in some parts of the throat there are blood vessels as well as lymphatics almost completely blocked up by fibrin, or filled with colourless and other cells. But as we shall mention hereafter there are other considerations to be kept in view before accepting this dependence of the obliterative changes on embolism.

In connexion with the interstitial inflammation of the cortex we have to mention similar changes of the urinary tubes as in the preceding case, viz., flooding of the tubes with exudation-cells, and subsequent disappearance of their epithelium, blocking of tubes with fibrinous and cellular masses or with cylinders composed of more or less swollen cells. A few hyaline cylinders, and also amorphous (lime) masses deeply stained in hæmatoxylin. The epithelium of many convoluted tubes shows cloudy swelling, granular and fatty degeneration.

Many descending branches of Henle's loops of papillary part are filled and blocked by deeply-stained (lime) masses or by coarsely or finely granular cylinders.

The epithelium of large collecting tubes of the papillary portion of pyramids appears more or less detached from the membrana propria; in a few instances the epithelium has collapsed and shrunk, into an opaque, relatively small, excentric mass attached to one part of the membrana propria.

The epithelium lining the ascending branches of Henle's loops is also more or less detached from the membrana propria.

There is a considerable amount of pigment in descending branches of Henle's loops of the basis of pyramids.

The muscular nuclei not only of small arterioles but also of the larger trunks are germinating; especially in the latter the muscular coat appears distinctly thickened. In the former the increase of nuclei is well seen at the point of entrance into the Malpighian corpuscle, no matter whether there is or is not an embolus present.

It is remarkable that the urine contained no albumen.

Case 19.—In this case the interstitial inflammation is much more extensive. The tissue around the large vascular trunks is at some places very densely infiltrated, and this infiltration extends also into the basis of pyramids for some distance and into the cortex; in the latter it comprises in some places indiscriminately the medullary rays as well as the tissue between them. Besides places where the cortex is one diffused mass of infiltrated tissue, there are others where only the interlobular artery is surrounded by tissue that has great resemblance to adenoid or lymphoid tissue. The muscular wall of the artery is thickened in a conspicuous manner. The infiltration may be traced from the basis of pyramids throughout the different parts of the cortex. Near the capsule the cortex appears at some places for a considerable distance transformed into a densely infiltrated tissue, in which are discernible more or less degenerated Malpighian corpuscles and

outlines and remains of urinary tubes. The same is the case, to a greater or lesser degree, in those parts in which the infiltration with lymph-cells has reached a high degree.

The greater number of exudation cells contain two or three small nuclei like colourless blood corpuscles.

There are few Malpighian corpuscles which do not present a great abundance of nuclei and are marked by a more or less great opacity of their glomerulus. The cavity of Malpighian corpuscles and of many convoluted tubes contains granular matter and what appears to be remains of decolourised blood corpuscles. As may be expected there are urinary tubes in the pyramids containing numerous exudation cells. The urine examined after death contained albumen.

Finally the thickening of the muscular wall of arteries has to be mentioned.

Case 20.—The interstitial nephritis is still more advanced in this case, but it is limited almost entirely to the cortex, there being only few places where the infiltration with lymph-cells of the tissue around the large vascular trunks extends also into the pyramids. In stained preparations the infiltrated parts are very easily recognised with the unaided eye. The infiltration is either diffuse, *i.e.*, the tissue of the cortex, irrespective of the different sections, becoming gradually more or less densely crowded with lymph-cells, or these latter form cords, a sort of sheath, around interlobular arteries. In the latter case the infiltration bears the greatest resemblance to adenoid tissue, the muscular wall of arteries being at the same time thickened.

All that has been said in the preceding case with reference to the urinary tubes becoming flooded with lymph-cells, and in consequence of this the disappearance of their epithelial cells as such—when the epithelial cells become disunited it is very difficult to recognise them—holds good also in this case. Where the interstitial new growth has reached a certain high degree, and where in the course of preparing the specimen the cellular elements representing the infiltration have become removed, it is seen that they are embedded in a more or less dense network of membranous structures to which is attached here and there a slight amount of granular matter, perhaps remains of disintegrated epithelial cells.

The large venous vessels and the vessels next the capsule are distended and filled with blood.

In parts with considerable interstitial change urinary tubes are to be met with, chiefly Henle's tubes, filled with hyaline cylinders and also with hyaline blocks, the latter in some cases still recognisable as composed of swollen degenerated cells.

A very striking effect is produced by staining these preparations with acetate of rosaniline, for the interstitial new growth, or rather the nuclei of the cells constituting it, and the nuclei of the epithelial cells of urinary tubes, appear of a pink-violet colour; both the normal as well as the degenerated Malpighian corpuscles, the blood vessels, connective tissue, the hyaline cylinders in the urinary tubes, and the membranes of urinary tubes, are of a pale blue colour.

There is granular and fatty degeneration of the epithelium of some convoluted tubes.

The urine did not contain albumen.

The next cases deserve as much attention as those we minutely described in the preceding pages, but I should be afraid to weary the reader if I were to repeat all the appearances mentioned in the last two or three cases over again, for, as may have been already expected by

this time, we should probably find interstitial nephritis of a more advanced degree in cases where death has set in at a later period than in the preceding two or three; and this is actually what we find in—

Case 21.—The infiltration is very intensive in the tissue of calices, and extends hence into the tissue surrounding the large vascular trunks, and further into the cortex and the basis of the pyramids. There are also here extensive parts of cortex which show considerable infiltration, amounting to more or less total disappearance of urinary tubes, but we have to notice likewise the presence of cords of infiltrated tissue closely resembling adenoid tissue forming a sheath round interlobular arteries, the muscular coat of which is at the same time thickened, the nuclei of the muscle-fibres being actively germinating. From the sheath of the artery the infiltration extends between the urinary tubes for a variable extent.

All that concerns the changes of epithelium of urinary tubes and their contents, in infiltrated as well as in uninfiltrated parts, as described in the preceding cases, is likewise to be observed in this case, with the addition that the hyaline cylinders are relatively numerous in the tubes of pyramids, where there are also tubes filled with cylinders composed of swollen degenerated cells, and further cylinders composed of more or less coarsely granular matter, or of that globous material which we previously declared to be lime matter. With reference to the last-named structure I have to mention one interesting fact, which is this: there are branches of Henle's loops in the papillary part, the epithelial cells of which are changed in some parts into granular cells of considerable dimensions; now within these cells, and extending also into the lumen of the tube are droplike or oval hyaline bodies fused together so as to form cylinders, or the epithelium contains globular transparent structures very sharply outlined and in their outline deeply stained. These structures are forming chains of a more or less complicated nature; they are in some instances plugging the whole tube. In one instance I have distinctly seen a portion of such a chain perforating the membrane of the tube so that a small part of the chain was lying outside, just as if a mycelium had grown through the tube. *See* Fig. XXXIX. In some tubes this material looks as if composed of spherical or oblong sharply outlined cells—about a little smaller than coloured blood corpuscles—possessed of a very thick cell wall stained deeply with hæmatoxylin, and as if they formed longer or shorter more or less complicated (branched or lobed) chains. These quasi-cells vary, however, very much in size, and are, no doubt, of an inorganic nature, probably lime salts. At some places they do not desemble nuclei of epithelial cells in the act of germination. It is not the individual particle of the material in question upon whose nature we are to make a definite diagnosis, but it is here as in many other circumstances, the relation of these particles towards each other and the surrounding elements, their grouping, their aspect, and the different conditions in which they are met with, upon which a diagnosis is justified. In this case we have only to look at different tubes of the papillary part to see that between the cylinders composed of the above-mentioned chains of globous bodies, and those deeply-stained more or less amorphous irregular lumps by which some tubes are completely blocked up, there exist all transitional forms. And this is one of the chief reasons why I regard the substance in question of the nature of urinary salts, which have been precipitated either on their way into the epithelium, or in this latter.

From a careful study of the relation of these masses to the urinary tubes I have come to the conclusion that they are contained originally

in the epithelial lining, even where they form large masses by which the tube becomes blocked up and distended. Where this has reached a high degree it is understood by itself that the epithelium has given way and disappeared altogether.

The coarsely granular masses are chiefly contained in large collecting tubes, whereas the above-mentioned lime matter is found chiefly in Henle's tubes.

The epithelium of the large ducts is transparent, the interepithelial nucleated septa extending from the membrana propria between the epithelial cells are very distinct. Some epithelial cells are very much swollen and transformed into goblet cells.

In a few ducts the epithelial lining is detached from the membrana propria, opaque, folded, and shrunk. A similar condition is observed in the epithelium of some collecting tubes of cortex.

Case 22. — Here we have interstitial nephritis of the same character as in the preceding cases. There is to be mentioned the fact that the blood vessels, capillaries, and veins of the periphery of the cortex are in some parts distended and filled with blood; these parts not very extensive and are marked by a diffuse infiltration of the intertubular tissue with more or less numerous lymph-corpuscles, the epithelium of the urinary tubes of these parts being detached from the membrana propria. The same condition with regard to tubes and blood vessels is present in some parts of the basis of pyramids.

The changes of the epithelium of convoluted tubes are very marked, consisting in cloudy swelling in some, granular and fatty degeneration in others. Numerous tubes (Henle's ascending branches) in cortex contain hyaline cylinders, others contain cylinders composed of cells more or less swollen up.

In some infiltrated parts where the epithelium of the urinary tubes is breaking up in consequence of being overcrowded by lymph-corpuscles, some of the epithelial cells possess two or even three nuclei.

With reference to the urinary tubes of pyramids there is one fact especially to be mentioned, viz., the membrana propria of large collecting tubes, as well as the intertubular and intervascular connective tissue of some parts of the papillary portion of pyramids, is swollen up and converted into a homogeneous substance. Some of the tubes of Henle contain masses composed of smaller or larger droplets, similar to fat-droplets, but they are different from true fat-droplets inasmuch as they are not dissolved by alcohol, oil of cloves, &c. There are also tufts of what appears to be fatty crystals contained in some Henle's loops.

The epithelium of ascending branches of Henle's loops and of many collecting tubes is detached from the membrana propria, and is in some instances breaking up into small fragments.

Case 23.—This forms the last case; as the reader remembers from the first chapter, this patient had recovered from the acute attack of scarlatina, when he was taken ill with pneumonia, on the eighth day of which he died. The changes that I found in the kidney are as follows :—

Many glomeruli show an abundance of nuclei; in some of them the capillary vessels are very indistinct, being replaced by an opaque or granular substance in which the nuclei appear to be obliterated.

In some arteries the wall is much thickened, owing to the increase of muscular tissue, but also the nuclei of the endothelium appear to be increased in numbers. In a few instances I have seen arterioles in a state

of obliteration. There are present in some parts of cortex a few lymph-corpuscles between urinary tubes and also around arterioles. The same condition is met with in the basis of pyramids. The chief changes, however, are to be observed in the urinary tubes; in some of the convoluted tubes is contained granular matter and blood; the epithelium is in a state of disintegration. In some ascending tubes of Henle of cortex and likewise in some collecting tubes of pyramids the epithelium is detached from the membrana propria and breaking up into granular fragments. The epithelium of large collecting tubes of the papilla is entirely gone.

Many ascending tubes of Henle and also collecting tubes of cortex contain hyaline cylinders and cylinders including more or less changed blood corpuscles. The same is also the case with many tubes of pyramids.

There are numerous tubes in the cortex (a few also in papillary part), chiefly Henle's tubes and collecting tubes which contain the deeply-stained (lime) matter.

B.—*General Remarks on the Anatomical Changes of the Kidney.*

If we now summarise the results of our examination, we may, I think, without reference to any theory, divide them into (1) those belonging to the early, and (2) those belonging to the later changes.

1. Amongst the former we found (*a*) the peculiar degenerative changes of arteries and Malpighian corpuscles, (*b*) the germination of nuclei in the wall of arteries and in the glomerulus, and (*c*) slight alterations of the epithelium of certain tubes in the cortex and pyramids.

(*a.*) The intima of arterioles of cortex undergoes a peculiar change, swelling up for a greater or smaller part of the circumference, and for a various extent into a hyaline substance which is of a bright glassy aspect, and as the process advances splits more or less distinctly into fibrillæ. This change occurs generally on the afferent arteriole next the Malpighian corpuscle; it may lead in some cases to a perfect occlusion and obliteration of the vessel, the change having spread to all layers of the wall. A similar process is to be observed also on the glomerulus of Malpighian corpuscles; in the slighter degrees the wall of capillary vessels appears from place to place thickened, having swollen up into a hyaline substance, it is granular and opaque, and the nuclei are germinating very much; these nucleated masses become more or less fused into a hyaline material, which finally undergoes a more or less distinct fibrous degeneration. The capsule of the Malpighian corpuscle during this time is much thickened, at first homogeneous, containing many oblong nuclei, and then also becoming fibrous.

(*b.*) The nuclei of the endothelium and especially those of the muscular coat of arterioles are in a state of active germination; this is chiefly observed in afferent arterioles, but also in interlobular arteries and even in the large arterial trunks; the wall of some of the afferent arterioles and interlobular arteries is conspicuously thickened. Where the hyaline degeneration of the wall of an arteriole has advanced to a certain degree, very little or nothing is left of the muscular coat.

(*c.*) We observed swelling up of epithelium of some convoluted tubes and germination of the nuclei of the epithelial cells, especially conspicuous on a portion of a cortical ascending tube of Henle lying next to an afferent arteriole. Granular matter and blood in Malpighian corpuscles and some portions of convoluted tubes was almost generally

observed; also slight cloudy swelling and granular disintegration in some tubes of cortex. The changes of the tubes of the pyramids were only very slight. This is very much in accordance with the observations of other pathologists, although I think my observations refer to earlier cases. With the exception of the conspicuous increase of nuclei of a certain part of a cortical ascending tube of Henle, the other changes of urinary tubes are devoid of a special significance, being no doubt dependant upon the congestive condition of the kidney. The loose connexion of the epithelium with the membrana propria in ascending branches of Henle's loops of pyramids and of the large collecting tubes of this same region, especially of the papilla, is, no doubt, a result of the same condition. But whether the removal of the epithelial lining of some of the last-named tubes, as observed in some cases, is taking place intra vitam or post mortem is not easily ascertained. Rindfleisch on the occasion of desquamative catarrh of the kidney (Handbuch der Pathologischen Histologie, p. 448), says that on applying lateral pressure on the papilla of any not quite fresh kidney, one invariably expels a certain amount of epithelium from the urinary tubes, and we are therefore, from the absence of the epithelial lining in sections, not justified in concluding that this absence indicates that the epithelium had been removed intra vitam. Looking now at our cases, and considering that the kidneys were obtained and put into the hardening fluid in many instances within a short time after death, that in some of the cases the urine did not contain albumen, and that the epithelium of the collecting tubes did not show any conspicuous alteration, it seems probable that the absence of the epithelium in the collecting tubes is not a purely accidental symptom. The fact that in some of the collecting tubes the epithelium is occasionally seen to break up into small granular elements is no doubt greatly in favour of the non-accidental character of the symptom in question. On the other hand, it must be admitted that "the abundant production of young cells by the connective-tissue "around the urinary tubes inducing a secretion of numerous young "cell-forms" (Rindfleisch, l.c., p. 449), as chief part in desquamative catarrh, is altogether absent in our early cases.

With regard to the changes of arterioles and Malpighian corpuscles above mentioned, there is very little known hitherto. Klebs (Handbuch der Pathologischen Anatomie, III. Lief. p. 645) describes under the name of glomerulo-nephritis a condition of the kidney which he found in scarlatina during the period of desquamation, when the patients appeared to have been perfectly convalescent. There was œdema of the face, &c., then scarce urine, or complete retention, followed on after by uræmic poisoning. "In the post-mortem examination the kidneys "are found slightly or not at all enlarged, firm . . . . , the parenchyma "very hyperæmic. Only the glomeruli appear on close inspection pale, "like small white dots. The urinary tubes are often not changed at "all, occasionally the convoluted tubes are slightly cloudy. The micro-"scopic examination shows that there are neither interstitial changes "nor germination of epithelium, the so-called renal catarrh, generally "supposed to be present under those conditions on account of the "absence of other perceptible derangements, and there seems therefore, "leaving out the glomeruli, the congestion of the kidney alone to "remain to account for the symptoms during life. That this, however, "is insufficient no one can doubt, knowing that in equally intensive "active as well as passive hyperæmia, *e.g.*, in CO poisoning and in "passively congested kidney, complete anuria and acute uremia never "happens." On microscopic examination of the glomeruli it is seen that "the whole space of the capsule is filled with small somewhat angular

nuclei, embedded in a finely granular mass." "The vessels of the glomerulus are almost completely covered by nuclear masses." Klebs has convinced himself that we have to do here with a germination of the cells in the interstitial connective tissue of the glomerulus (first pointed out by Axel Key), in consequence of which the vessels of the latter become compressed.

As the reader probably remembers, we have observed in all our early cases the great abundance of nuclei of the glomerulus, but a condition like that described and figured by Klebs (Fig. 72, p. 646), I have met with only in very few glomeruli. I am not less certain that in our cases the nuclei of the epithelial elements on the surface of the capillary blood vessels of the glomeruli are germinating, being either in state of division or already divided. Of these epithelial elements Klebs only mentions that in some cases they are fattily degenerated, a condition which in these early stages I have never met with. The cases of Klebs (I cannot gather from his description how many cases he refers to) were, I have little doubt, different from those I examined, for a general condition of the glomeruli as described by this observer, and such an excessive germination of nuclei that the blood vessels are completely compressed, was not seen in one of the 23 cases I have examined. In two cases, 9 and 10, the kidney had been injected artificially very soon after death, and it was found that with one or two exceptions all glomeruli are permeable, a result at which I was not a little surprised, for in uninjected preparations many glomeruli give one the impression of being impermeable, a condition which Rindfleisch well appreciated under other circumstances, and therefore rightly advises to examine the injected kidney. I must therefore question whether the anuria and uræmic poisoning in scarlatina, when the kidney does not show any conspicuous catarrhal or other changes, is due to a *compression* (Klebs) of the vessels of the glomeruli by the nuclear germination. I am inclined rather to insist on the changed state of the arterioles. In all our cases we have seen an overgrowth of the muscular tissue in the arterioles; and if this may be taken to express that under the influence of some stimulus (perhaps some blood irritant) which the disease supplies, the arterial muscular tissue has been exceptionally exercised; query, whether this exceptional exercise of contractility, affecting the calibre of arterioles, may during life shut the glomeruli out of the circulation, and may thus, so far as it operates, suppress the secretion of urine.

The degenerative changes of arterioles and Malpighian corpuscles which we described in our early cases have not been noticed by any of my predecessors. A hyaline degeneration of vessels, it is true, has been described before now, but not in the kidney of early cases of scarlatina. Thus Gull and Sutton (Medico-chirurgical Transactions, volume 55, 1872, p. 273) observed a peculiar alteration of arterioles in chronic Bright's disease, which (alteration) has a certain resemblance to that noticed in our cases. These authors found (l.c., p. 283):

"(1.) That the arterioles, throughout the body in that condition usually called chronic Bright's disease with contracted kidney are more or less altered.

"(2.) That this alteration is due to a "hyalin-fibroid formation in the walls of the minute arteries, and a hyalin-granular change in the corresponding capillaries.

"(3.) That this change occurs chiefly outside the muscular layer, but also in the tunica intima of some arteries.

"(4.) That this change in different organs varies in different cases.

"(5.) That the muscular layer of the affected vessels is often atrophied in a variable degree."

The chief difference between us is, that in my cases the hyaline change is limited entirely to the intima of arterioles. In both cases the hyaline change extends also on capillaries (*see* our observations about the capillaries of glomerulus).

Fr. Neelsen (Archiv. der Heilkunde, 1876, II. and III. Heft, p. 119) noticed in various cerebral diseases, in many acute infectious diseases (variola, typhus, morbilli, one case of scarlatina), and in various other diseases (syphilis, phthisis, pneumonia, dysenteria, rheumatism, &c.), the wall of capillaries of the pia mater considerably thickened, highly refractive, and of a lardaceous aspect. Generally only small portions of the capillaries are thus affected, most frequently at the point of branching into two or more branchlets. The nuclei of the endothelial cells of those parts are never normal, always shrunk. In a few cases Neelsen saw also in some isolated arterial branchlets passing into capillaries a thickening of the wall extending for a large distance, and consisting in a fusion of the intima, media, and adventitia into a colloid mass, in which at some places were included amyloid bodies. The chemical examination proved that the substance in question has similar properties as elastic tissue. Several observers (Lubimoff, Rudolf Arndt, Schüle, Adler, and Eppinger) had previously described a waxy, colloid, or glassy degeneration and thickening of capillaries and smaller vessels of the pia mater, and have associated this morbid condition of the vessels with certain diseases of the cerebrum; by the observations of Neelsen this conclusion appears unjustified. With regard to the development of that colloid or hyalin change of capillaries, Neelsen arrived at the conclusion that "the degeneration starts from the endothelium. The nuclei commence to shrink, the endothelial cells "become fused into a colloid mass, which extends excentrically into the "perivascular lymph space, and finally fills this completely . . . . . A "narrowing of the lumen seems to result not at all, or only in a very "slight degree." There can be no doubt that Neelsen observed a change which belongs to the same category as that noticed by Gull and Sutton. Neelsen's colloid degeneration bears likewise a great resemblance to the hyalin degeneration observed by myself on the arterioles and capillaries of glomeruli with this difference, that in our case the endothelium of the arterioles has nothing whatsoever to do with the degeneration in question; only very late, when all the layers of the arterioles become involved in the degenerative process, there is likewise a change of the endothelium. In the capillaries it is of course different, for their wall is only endothelium. Two points in Neelsen's observations are of very great interest to me: (1) the fact that the hyaline change affects very readily the vessels near their point of branching, and (2) that the hyaline substance in question is of the nature of elastic tissue; for in the kidney of our cases, the afferent arterioles undergo the change in question chiefly near their termination, *i.e.*, near the point of branching into the capillaries of the glomerulus, and the intima being the part of the arteriole which undergoes the hyaline degeneration, it is quite clear that for this reason this substance is of the nature of elastic tissue. I am inclined to think that in the arterioles observed by Gull and Sutton it is also an elastic layer which first undergoes the hyaline change; not the intima but the external elastic layer, *i.e.*, that separating the media from the adventitia. As I mentioned already, in the kidneys of our cases of scarlatina the hyaline change invariably attacks the intima, and only when the degeneration has proceeded far enough, also the other coats become more or less involved in the process.

In my paper "On the Minute Anatomy of Typhoid or Enteric Fever,"

(*see* these Reports, 1875,) I have described and figured a change of arteries of the intestine and spleen, which is the exact counterpart of the changes observed in the arteries in scarlatina; in that paper I called the change a deposit of colloid material between intima and media, but looking at the drawings and my old specimens again, I find that it is precisely the same hyaline degeneration of the intima of the vessel as in scarlatina.

Let us now pause for a moment and inquire into the cause and effect of the changes of minute arteries referred to in the preceding. On superficial consideration it seems reasonable to suppose that the germination of muscular nuclei of arterioles is a consequence of the degenerative change of the ends of arterioles and of capillaries of glomeruli; that is to say, inasmuch as by the swelling of the intima at the termination of afferent arterioles, and a corresponding swelling of the wall of some of the capillaries of the glomerulus, the resistance, already great under normal condition, becomes excessive, the muscular coat of the afferent arteriole will become hypertrophied. This, as I said, seems at first sight an admissible explanation, but looking carefully at the facts I do not regard it as the correct one. The chief reason for saying so is this: the number of arterioles and glomeruli in which the above degenerative changes may be observed is very small as compared with the number of arterioles and arteries, whose muscle nuclei are in a state of germination. In several of the above cases we have seen the great increase of muscle-nuclei and hypertrophy of the muscular coat in even large arterial branches of kidneys where only very few arterioles and Malpighian corpuscles presented the changes in question, and therefore I cannot but think that the germination of muscle nuclei in arteries is in no way dependent upon the hyaline degeneration of vessels. Besides the additional amount of resistance caused by this hyaline swelling could not in early stages be so great as to cause so conspicuous a hypertrophy of the muscular coat we actually meet with in a great number of arteries.

I am inclined to think that both the hyaline degeneration and the germination of muscle nuclei we meet in earlier stages are two concomitant symptoms, caused probably by the same agent. Why should not peculiar conditions of the blood—(not exclusively the scarlatinal state, for the hyaline degeneration occurs as we mentioned in many other pathological conditions, acute infectious and other febrile diseases, cerebral diseases, &c.)—affect the walls of the vessels in that peculiar way? and if the blood coagulates when in contact with the non-healthy wall of a vessel, why should not vice versâ a morbid condition of the blood react on the wall of the vessels, considering the intimate relation that exists between the two tissues? I am of course far from denying that if in our cases or others the end of an arteriole becomes narrowed, the wall of the arteriole will cæteris paribus become hypertrophied; but what I think I am justified in saying is that the germination of muscle-nuclei and the hypertrophy of the muscular coat, as observed in earlier stages of scarlatina, are not dependent on the hyaline degeneration of the intima of the ends of arterioles and of capillaries of glomeruli, but that both are probably dependent on the same cause lying in the blood itself. We shall see afterwards that the hypertrophy of the muscular coat is found also in other organs, *e.g.*, tongue, epiglottis, tonsil; of the same condition in the arteries of the skin we have already had occasion to speak, where no such hyaline degeneration of the intima can be ascertained. And finally we shall have to mention, on the occasion of the spleen, that very extensive hyaline degeneration takes place in arteries without any conspicuous hypertrophy of their muscular coat. All these facts are to be considered in discussing the relation of the two processes towards each

other, viz., the change of the muscular coat and the hyaline degeneration. As the reader may have already observed, all these facts do not seem to be quite in conformity with the hypothesis hinted at in a former page of this memoir, viz., that the degenerative changes of the arterioles are due to embolism.

Not less important is the question what effect has the degeneration of arterioles, and especially that of Malpighian corpuscles? I think I am safe in saying, none which is clinically appreciable; there is in some parts a slight increase of the connective tissue around—chiefly increase of nuclei, sometimes also a few round cells; but the number of Malpighian corpuscles undergoing the hyaline and fibrous degeneration is after all not large enough to have any but slight effect. In later stages when interstitial nephritis has become a conspicuous feature the number of Malpighian corpuscles degenerated in the above-manner is not greater in some cases than in the earlier stages. The explanation that the degenerative changes of arterioles and Malpighian corpuscles should not have any other than a slight effect is, I think, not only due to the *relatively* small number of arterioles and Malpighian corpuscles affected in that manner, but probably chiefly to the slow progress of that degeneration, so that sufficient time is allowed for the surrounding vessels to adapt themselves to the new conditions. Before leaving this question of the hypertrophy of the muscular coat of arteries of the kidney I must mention that such a condition has been, so far as I know, first pointed out by Dr. George Johnson in Bright's disease; his view on the causes of that condition of the arteries is too well known to be here gone into.

When describing some of the earlier cases I intentionally laid some stress on the fact that the degenerative change of arterioles and Malpighian corpuscles is not subsequent to interstitial nephritis; and if hereafter we shall mention the condition represented in Fig. XIII., in which two more or less degenerated Malpighian corpuscles are seen to be surrounded by inflammatory products, the reader will have to bear in mind that this condition is very well compatible with the above proposition, for as we shall mention below, the inflammatory condition and degeneration of Malpighian corpuscles *in this and in similar instances* are caused by one and the same agent, *i.e.*, embolism of afferent arterioles.

There is one other point which is of great interest to the pathologist; it refers to the presence of granular matter and remains of blood so often observed in Malpighian corpuscles and convoluted tubes in portions of the kidney in many of the earlier cases. That this granular matter is partly due to exuded and coagulated albuminous matter and partly to the disintegration of epithelial cells, has already been mentioned, and likewise that the urine in some of the cases did not contain any albumen. The explanation of this phenomenon may be either that the quantity of albumen passing out of the kidney into the urine is after all too small to be detected, or that the albuminous matter present in the above-named localities does not leave the kidney at once, but remains stationary or almost so for a longer or shorter time. This latter seems to me to be more probable, since it is a fact well known to physicians that albumen may appear and again disappear in the urine of scarlatina patients in a very irregular manner and without any appreciable cause, as far as the general character of the disease is concerned. Is it not probable that either in consequence of the above-mentioned cramp of arterioles (*see* a former page), and subsequent impeded circulation and secretion in the corresponding parts of the cortex, the exuded matter is not carried away from the convoluted tubes until that cramp of arterioles passes off and the secretion is resumed again?

2. We come now to the later changes, as which we have particularly described (*a*) the appearance of the round cells, lymphoid cells, or whatever they may be called, in the connective tissue of the kidney, *i.e.*, the interstitial nephritis, and (*b*) certain concomitant alterations of the urinary tubules. As we have mentioned above in detail already, (*see* first part of this chapter) the infiltration with round cells is observable at the end of the first week in the connective tissue around the large vascular trunks, (which is a continuation of the deeply-situated connective tissue of the calices) whence it spreads into the basis of the pyramids, and especially into the cortex. The gradual increase in extent and intensity of this infiltration is so decided in our cases (*see* cases 11, 18), that I have no hesitation in concluding that the interstitial nephritis, when it does take place, commences about the end of the first week as a slight infiltration of the tissue around the large vascular trunks, and cæteris paribus gradually increases to such an extent that portions of the cortex, very seldom portions of the basis of the pyramids, are converted into a pale, firm, round-cell tissue, in which the original urinary tubes of cortex become gradually quashed and lost. Some of the urinary tubes contain hyaline or more or less swollen cellular cylinders, others show granular or fatty degeneration. We have pointed out before that the changes in question of the urinary tubes, in parenchymatous nephritis, viz., crowding of urinary tubes with lymphoid cells, granular and fatty degeneration of epithelium of urinary tubes, and cylinders of different kinds in the tubes, become distinct after the interstitial changes have reached a certain high degree, and that they are quite insignificant before this degree of interstitial nephritis is attained. The infiltration of cortex with round cells is first observable at the roots of the interlobular vessels, whence it spreads very rapidly towards the capsule of the kidney, and also laterally among the convoluted tubes around the Malpighian corpuscles. The infiltration is at first limited to the tissue between the medullary rays, *i.e.*, the parts around the interlobular vessels; later on it encroaches also on the medullary rays and attacks extensive portions of the subcapsular region. In the course of this process considerable parts of the peripheral cortex—occasionally of a more or less distinct cuneiform character with the basis nearest the capsule of the kidney—become converted into whitish, firm, bloodless, cellular masses, in which Malpighian corpuscles and urinary tubes cannot be more than imperfectly recognized. When the infiltration of cortex has reached so high a degree that it can be perceived in a section already with the unaided eye, it will be found that many Malpighian corpuscles in the midst of the foci of infiltration have more or less completely degenerated into fibrous masses, containing the remnants only of nuclei; this degeneration is not to be confounded with the degeneration observed in the earliest stages, when no interstitial inflammation has made itself felt as yet.

The infiltration of the pyramids was altogether of rare occurrence in our cases, it did not exceed the basis of the pyramids, and was altogether limited to the surroundings of the vasa recta.

That in some cases the infiltration in the cortex, especially around interlobular arteries, presents all the characters of adenoid or lymphatic tissue, *i.e.*, more or less dense reticulum of fibres or membranous structures, in the meshes of which lie embedded chiefly uni-nuclear lymph-cells, has been mentioned in detail in the first part of this chapter, and likewise that in the course of the increase of the round-cell tissue between convoluted tubes the epithelium and the membrana propria of these latter are gradually losing themselves in the new growth.

It is not necessary for me to dwell any more on the characters of the interstitial nephritis in our cases, for they are in every respect

identical with the earlier stages of interstitial nephritis in general, not only as regards the nature of the cell-infiltration, but also that of the urinary tubes (*see* Rindfleisch, l.c., p. 458). From the preceding description and from the drawings accompanying this paper, it is established beyond doubt that we have to do with that condition, viz., interstitial nephritis, and what is of paramount importance, that this change makes its appearance already at the end of the first week, and after this time gradually goes on increasing. In order to remove any misunderstanding I will add that I am speaking only of my own cases, *i.e.*, of cases which died in the course of, and from, scarlatina; my remarks on the interstitial changes do not refer to those that recover, or those that die in the course of scarlatina through another disease.

The most important question with reference to the interstitial nephritis is that of its intimate ætiology. In reviewing the above-mentioned changes with a view to ascertain how far they may be directly concerned in causing the interstitial inflammation we may without much hesitation dismiss: (*a.*) the degenerative changes of arterioles and Malpighian corpuscles as occurring in the earlier stages; they cannot be the inducing cause of the interstitial nephritis, considering that the latter is, in respect of locality, altogether independent of those degenerative changes; (*b.*) the changes of urinary tubes; this point we have already discussed and dismissed before. Remains now the embolic process. The presence of emboli, which we found in case 18 so abundantly, and which we described fully on a former page, was in that case, I think, clearly the cause of the interstitial nephritis. In connexion with this it must be borne in mind that the degenerative changes of the arterioles so often mentioned is probably of no small import for the embolic process, for the simple reason that an arteriole become considerably narrowed by the local hyaline degeneration of its intima and therefore impermeable for formed material of a certain size that happens to be circulating in the vascular system. That abnormal masses of formed material are carried into the blood from the different seats of inflammation (skin, throat, lymphatic glands) in the earlier stages of scarlatina is a point which does not require any proof. Granted the affluxus of abnormal masses of formed material into the circulating blood, it becomes very probable that considering the condition of the blood—being very easily coagulable, as is shown by the masses of fibrin present in blood vessels of the different organs—these masses may become centres of fibrinous deposits, and thus by their increasing size may become a source of extreme danger.

From the identity of the appearances respecting the interstitial nephritis of case 18 with those of the other cases of the same category, it would seem possible that also in the latter the interstitial inflammation may have been caused by emboli; but in fact such were not seen.

In conclusion, we have to mention the very curious fact of the deposit of what we regarded as lime-matter in the epithelium of urinary tubes, first of cortex, then also of pyramids, at a relatively early stage of scarlatina, and at a time when otherwise the kidney shows but little change. Is this deposit or precipitate of lime-matter due to an abnormal amount of it in the blood, or is it not rather due to some sort of abnormal functional condition, of the epithelium? The latter seems to be the more probable explanation.

We have now to see in what manner my assertions of the changes of the kidney coincide with, or differ from those of previous observers. As we have had occasion to state, there were only very slight changes in the urinary tubes; in the earlier stages where no interstitial nephritis was present, they could be detected only on very careful

examination of stained sections of well-prepared material. My cases are therefore different from those of some other writers (the literature of this subject see in Professor Thomas's Article) whose observations refer to cases of well-marked parenchymatous nephritis.

With regard to the interstitial change of the kidney in scarlatina Thomas says, (l.c., p. 230) "Circumscribed inflammatory masses are "found diffused throughout the stroma, or only at certain points of the "same, resembling abscesses and composed of small round cells, the "whole presenting an appearance of interstitial or purulent nephritis." From this not very circumstantial description I am unable to see whether Thomas merely refers to the cases he quotes from E. Wagner and Biermer, or whether he regards this as an usual occurrence, and if so at what stage or stages does it occur? Beyond those sentences there is nothing to indicate that in the majority of cases of nephritis anything else is meant but parenchymatous nephritis.

Biermer (An unusual case of Scarlatina, Virchow's Archiv. Bd. 19, p. 537), in a case of scarlatina in a boy of $5\frac{1}{2}$ years old, which lasted from May 4th until June 8th, 1858, finds the following condition of the kidney: both kidneys are much enlarged, about as large as in the adult; "they have also experienced an extensive and recent new "formation of connective-tissue, in such a manner that the stroma is "very marked with many nuclei, whereas the urinary tubes are filled "with delicate, partly somewhat irregular, slightly granular, otherwise "unaltered, cells. In the cortex, and still more distinct in the basis of "the pyramids, numerous roundish white patches may be perceived of "about the size of hemp-seeds." On microscopic examination it is found that these white patches are due to masses of small stellate cells very closely situated, and thus almost perfectly concealing the other tissues. Similar connective-tissue new growths were present in the liver and spleen; of this, see below.

E. Wagner (Beitrag zur Pathолog. Anatomie der Scharlachs, Archiv. der Heilkunde, 1867, p. 262) records a case of scarlatina with "lymphatic new growth" in the kidney. This refers to a lad of 17, who died after 48 hours' illness. "The cortical part of the kidney "contained numerous small circumscribed groups of cells and nuclei, "partly and chiefly in the next neighbourhood of Malpighian cor-"puscles, which latter were of smaller size. All the epithelial ele-"ments of the kidney show a greater or smaller albuminous (cloudy) "swelling, especially those of Henle's loops. Considerable numbers "of urinary tubules contained either pus-corpuscles only, or besides "the latter also epithelial cells showing albuminous (cloudy) swelling." Similar lymphatic new growths were present in the liver and spleen of this and a second case, of which more hereafter.

Dr. T. Coats describes (in British Medical Journal, 26th September 1874) a case of "acute interstitial inflammation of the kidneys in "scarlet fever, fatal on the tenth day." At the post mortem examination both kidneys were much enlarged. They presented to the naked eye very much the appearances of the large white kidney, the cortical substance being very pale and much increased in thickness. "The microscopic characters in this case were quite unequivocal. "The enlargement and paleness of the kidney were due to an infil-"tration of the cortical substance in almost every part by multitudinous "round cells. These were packed in between the tubules, separating "them, but not to any great extent destroying their epithelium. "The cells were about the size of white blood corpuscles." . . . . . "The epithelium of the renal tubules was very little changed, "perhaps slightly enlarged and granular." . . . . .

Klebs, l.c. p. 465, makes a short remark to the effect that there are "patients who sooner or later after the disease (scarlatina) has "passed away perish from diffuse interstitial nephritis and its sequelæ." From what we have shown it is clear that the case of E. Wagner, as well as that of Biermer and also of Coats, do not form any exceptions from the general rule which we have laid down, viz., that in all cases that die during and from scarlatina, after a certain time, generally after about one week, the kidney is the seat of more or less marked interstitial nephritis. At first the inflammation is so slight and the places of infiltration are so scarce, that it requires careful examination to detect them; they become well marked as the disease proceeds. If the stage is reached in which the foci of interstitial inflammation are numerous and extensive, the kidney shows a perceptible increase in size and a conspicuous increase in thickness of cortex, which at the same time is exceedingly pale. In the earlier stages, *i.e.*, when there are only slight interstitial changes, the kidney is not enlarged, and its cortex is not paler than is usually found at this stage of scarlatina. It is probable that the interstitial nephritis in many early cases (after the first week) has been overlooked by other writers on account of its very slight degree. Only in this way can I account, on the one hand, for the absence of a record of cases with slight degrees of interstitial nephritis, and on the other hand, for the case of E. Wagner, Biermer, and Coats being described as "unusual cases." According to me they are not unusual in manner, they are only unusual in degree. Wagner's case is, besides, unusual also as regards time.

IV.—Examination of the Organs of the Throat.

(A.) *In the above Cases.*

The organs of the throat, *i.e.*, tongue, palate, tonsil, pharynx, larynx, and trachea have been examined of Cases 1, 4, 5, 6, 9, 11, 20, and 22.

We shall describe in the first section of this chapter the results of the examination of tongue, palate, tonsil, and pharynx, and in another section those of the larynx and trachea.

1. *Tongue, Palate, Tonsil, and Pharynx.*

Case 1.—The tongue shows in all parts signs of inflammation. They are enormous increase of the thickness of the epithelium; the nuclei of epithelial cells are very numerous in the deeper strata. The epithelium is much infiltrated with migratory cells, mostly containing two or three small nuclei like colourless blood corpuscles, these latter chiefly accumulating in the superficial layers of the epithelium in smaller or larger cavities; hence very little is left of the original epithelial cells in the superficial strata; only a honeycomb of membranous structures remaining in their place. A division and proliferation of the nucleus of the epithelial cells in the superficial layers may easily be proved (*see* Fig. XX.). In many parts, especially on and near the tops of papillæ fungiformes, the intercellular clear spaces previously mentioned (*see* the examination of skin in the first cases) are very distinct, and so are also the smaller or larger distensions of them, containing, as has been already stated, migratory cells.

At the side of the tongue there are extensive places where the epithelium as well as the subjacent mucous membrane and muscular tissue are converted into a firm, dry, opaque, necrotic mass.

The connective tissue of the papillæ is very much infiltrated with lymph cells, so that the papillæ are very much increased in length as

well as in thickness. The minute blood-vessels are much distended, and their endothelial nuclei increased in numbers. This is especially well shown when the wall of a small vessel is looked at in the horizontal view. Many nuclei show marks of division, or being situated in couples or small groups of three and four. A peculiar aspect is presented by the endothelial nuclei in some of the smaller vessels, viz., showing a longitudinal linear mark (*see* Fig. XXIV.). The nuclei of the muscle fibres of the wall of small as well as large arteries show the same proliferation of nuclei as was mentioned in the case of the arteries of the kidney.

The striped muscle fibres of the tongue, near the upper surface, show the interesting change that the nuclei of the muscle corpuscles have undergone a conspicuous proliferation, there being not only numerous examples of them in the state of division, or already divided into two or three, but—and this is of a very striking aspect—in many instances the proliferation has reached such an extent that long series of transparent small nuclei take their place (*see* Fig. XXII.), the number of these nuclei amounting from 10 to 30 and more. They are generally forming a lineal series along the longitudinal axis; occasionally, however, there is a small nest of them instead, or they form clusters at one or the other point of a series. A similar proliferation of nuclei is observable in the connective tissue sheath of the nerve branches.

With reference to the portion of the tongue, which, was converted into an opaque, hard mass, the whole tissue of the mucous membrane, as well as muscle, was filled with a fibrinous and granular matter, the original elements of the tissue, *e.g.*, epithelium connective-tissue fibres, nuclei and lymph corpuscles, muscle fibres, &c., having lost their outlines, and being transformed in some places into a débris-like mass.

At the root of the tongue the lymphatic follicles are very considerably enlarged, and many of them present a very peculiar appearance. Some of them, in stained sections which have not been shaken out, present the usual aspect of dense accumulations of roundish, deeply-stained nuclei; in others, however, only the peripheral part has retained this structure, whereas the greater or smaller portion of the centre is transparent and pale, showing few of the round and deeply-stained nuclei, in its greater part being composed of granular, flattened cell-masses of different sizes, and containing a variable number of transparent, sharply-outlined, oval nuclei. From cells with one such nucleus we pass to conspicuously large cell-plates, in the centre of which lie three, four, five, and up to 30 nuclei of the above description. The nuclei themselves are, like the cells, flattened, for when seen in profile, where they form a large collection, they appear like a narrow band composed of deeply-stained more or less staff-shaped bodies.

The epithelium of the folds and pits occurring at this part of the tongue, and also the epithelium of the mouth of mucous ducts, is much infiltrated with lymph corpuscles, the subepithelial adenoid tissue having at the same time grown into the epithelium to a greater or smaller extent. At the bottom of the folds there are distinct signs of proliferation of the nuclei of epithelial cells. At these places we find nests composed of concentrically-arranged layers of epithelial cells, the centre, which is of variable diameter, being formed by greenish blocks, which, as a comparative study teaches, are only epithelial cells that have become opaque and firm, having previously lost their nuclei.

The veins of this part of the tongue are much distended and filled with fibrin, in which are included very numerous colourless corpuscles. The lymphatic vessels are filled with colourless corpuscles.

The proliferation of the nuclei of unstriped muscle tissue of arteries,

and those of the muscle corpuscles of striped muscle fibres, is very conspicuous at the root of the tongue. In some of the nerve trunks of this portion of the tongue continuous homogeneous masses may be noticed within the sheath, which masses assume a bluish tint in preparations stained with hæmatoxylin; in unstained preparations they are not visible. It is probable that these masses are only some sort of albuminous exudation of an alkaline reaction.

Precisely the same appearances as in the root of tongue are to be met with in the tonsils, not only with reference to the epithelium of the mucous membrane, the endothelium and muscle tissue of blood-vessels, and the striped muscular tissue, but also with reference to the peculiar change of the central portion of lymph follicles, as mentioned before. There is a considerable amount of suppurative change and sloughing of swollen follicles in the depth of the tonsil.

The pharynx shows likewise inflammation, which is most intense next the tonsils, amounting, at those places, to ulceration. The further away the more the inflammatory symptoms decrease, *i.e.*, the less is to be seen of proliferation of nuclei of epithelial cells, infiltration with migrants of the epithelium and of the mucous membrane, changes in blood-vessels, and striped muscle tissue.

Case 4.—In this case we have precisely the same inflammatory appearances as in the preceding one, the changes at the root of the tongue in the tonsils and pharynx being of considerable intensity. In the tonsils there is sloughing in the depth and in the pharynx the mucous membrane appears under the microscope to be ulcerated over an extensive portion. In the root of the tongue, as well as in the tonsils, we find the same peculiar change of central part of some lymph follicles, being more transparent than the peripheral zone, containing only few round and deeply stained nuclei of ordinary lymph cells, and being chiefly composed of large flat cells with many nuclei.

In Fig. XXVII. I have represented this change as occurring in a lymphatic follicle of trachea, but as in the tongue and tonsil the change is identical, the figure may serve to illustrate what has been stated for the latter organs as well. I need hardly add that all the microscopic appearances of inflammation as detailed in the previous case, and referring to the condition of the epithelium, the mucosa, blood-vessels, nerves, and striped muscle tissue are precisely the same in both cases.

Case 5.—The tongue does not show so much inflammation as in the preceding cases, there being only moderate infiltration with lymph-corpuscles of the epithelium and the mucosa. As is usual the superficial layers of the epithelium are the parts which are most crowded with migrants, the residues of the epithelial cells forming a honeycomb, as it were, for the former. The papillae are much swollen, owing partly to the condition of the blood-vessels, and partly to the infiltration with lymph cells. The soft palate, which is much thickened, shows ulcerations of the mucosa of the upper surface, whereas the mucous membrane of the lower surface exhibits only a moderate amount of inflammation. The uvula is much swollen, and shows a considerable amount of inflammation.

The tonsils contain numerous small abscesses. We meet also here with lymph follicles changed so that, except a broader or narrower peripheral zone, the substance of the follicles has become transparent, being chiefly composed of large more or less flattened cells, with two, three, and more nuclei (multinuclear cells).

In this case the cells just mentioned have a distinctly yellowish tint under the microscope, which is very conspicuous in specimens stained

with haematoxylin, in which the unchanged peripheral portion of the follicles, containing closely aggregated small deeply-stained nuclei, is more or less distinctly blue.

Considerable inflammatory changes are observable in the mucous membrane of the pharynx, at some places the epithelium of the surface more or less destroyed by infiltration with lymph-cells.

Case 6.—The tongue shows much inflammation, the infiltration with lymph-cells of the epithelium covering the papillae is considerable at the basis, it decreases very much along the sides, and is very slight indeed at the apex.

In the root of the tongue many striped muscular fibres may be seen, the substance of which has become broken within the sarcolemma into several transverse blocks, parts of the striated substance disintegrating at the same time into granular matter. A similar desintegration may be observed in the striped muscle fibres of the uvula and pharynx. This latter is very much swollen, and shows under the microscope much oedema and a considerable amount of infiltration with lymph cells of the epithelium and mucosa, and chiefly of the tissue around the blood vessels. These latter are much distended and filled with blood, fibrin and colourless blood corpuscles.

The soft palate shows ulcerations of the mucosa of the upper surface, this latter being almost totally destroyed. The mucous membrane of the anterior surface is only moderately inflamed.

The tonsils show considerable sloughing of the enlarged lymph follicles.

The mucous membrane of the pharynx shows ulceration of the superficial and intense inflammation of the deeper parts. In the ulcerated parts of this organ, as well as of the soft palate of this and other cases, larger or smaller spherical or oblong or irregularly-shaped lumps of micrococci are found to penetrate from the surface into the depth for a greater or smaller extent. They are very easily traced by their peculiar purplish-blue colour these lumps assume in preparations stained in hæmatoxylin and by their resisting the action of caustic potash.

Case 9.—Inflammation of tongue is of moderate degree. Some arteries show distinct thickening of muscular coat, the nuclei of unstriped muscle fibres being in the state of proliferation. At the root of tongue lymph follicles much enlarged, many of them showing the transparent central part mentioned above. The same condition is found in the lymph follicles of tonsils, and in addition to this we find ulceration and sloughing of the superficial parts.

The soft palate and uvula show perhaps the most active inflammation, extensive parts being ulcerated. Moderate degree of inflammation is observed in the pharynx.

Case 11.—Considerable amount of inflammation of front part of tongue. Less so at the root. The soft palate shows ulceration of the mucous membrane of the upper surface, whereas that of the lower surface is not much inflamed.

The tonsil shows extensive sloughing of lymph follicles. It is not uninteresting to find in the depth of the organ sloughs in which are met with numbers of lumps of micrococci gradually displacing the disintegrating tissues. The blood-vessels of the adjacent parts are more or less plugged by fibrin, and some capillaries also by lumps of micrococci. These latter are easily recognized as blue lumps of uniform granulations. Caustic potash proves conclusively their vegetable nature.

In connexion with the tonsils of this case I must mention a fact to which I have already called attention, and which may be observed

the other cases, both in the tonsils and at the root of the tongue: is to the effect that the epithelium of the mucosa, penetrating as folds cylinders or rounded masses into the depth of the organ, becomes radually encroached on by the adjacent germinating adenoid tissue in ich a way that that epithelium at first becomes crowded with lymph ells, then gradually replaced by the adenoid reticulum and lymph orpuscles, so that finally, apparently only the nuclei of the original pithelial cells are left. These (nuclei) have all the while been under-oing division. The inflammation of the pharynx is distinct, but not f an intensive degree. The lymphatics are very much distended by lasma.

Case 20.—The tongue is moderately inflamed. Of interest is the ondition of the blood-vessels and nerves: the nuclei of the endo-helium of arteries, veins, capillaries, and the nuclei of the sheath of erve trunks are in a state of active germination, and many of them show ransverse or longitudinal linear marks (*see* Fig. XXIV.). The number f nuclei of unstriped muscle fibres of arteries, as well as larger veins, s also much increased. The veins are distended and filled with brin and covered not only inside, but also outside, with colourless blood orpuscles. Some of the arterial vessels show the same hyaline degene-ation of intima as mentioned in the kidney. In the rest of the organs f throat the usual appearances.

Case 22.—There is considerable inflammation of the mucous membrane t the root of tongue. Some of the enlarged lymph follicles show the entral part transparent, and chiefly composed of large more or less ellowish tinted cells with large nuclei. The mucosa contains large oarsely granular migrants, which assume a deep blue colour in hæma-oxylin. The rest of the organs of throat show intensive inflammation, vith the usual symptoms.

2. *Larynx and Trachea.*

Case 1.—The epithelium covering the epiglottis, and especially its osterior surface, shows much inflammatory change, and the superficial nfiltrated layers are undergoing more or less desquamation. Near the ree edge of the epiglottis the epithelium of the posterior side becoming radually opaque, thinned, and raised from the mucosa, and finally ltogether detached, so that a total defect of the epithelium on the osterior surface is found next the margin of the organ. The epithelium f the anterior surface shows much less inflammatory change, *i.e.*, proli-eration of nuclei, infiltration with lymph-cells, and desquamation of superficial cells. The mucous membrane shows corresponding changes; hat of the posterior surface is transformed into a firm, dense plaque of denoid tissue, which here and there shows spherical or elliptical en-argements, that is to say, the lymphatic follicles of the posterior surface f the epiglottis have so much enlarged that they have become fused into ne continuous plaque. The adenoid tissue decreases very much in mount near the margin, and is altogether absent in the mucosa of the nterior surface; in this latter there is infiltration with lymph cells only in the subepithelial layer. It is interesting to notice that the same change of lymph follicles that we observed in the root of tongue and tonsils is also to be observed in those of the posterior surface of the epiglottis, *i.e.*, the central portion being very transparent, owing to the disappearance of the ordinary small lymph-cells with deeply-stained circular nuclei, and the presence of transparent large multinuclear endo-thelial cells. The blood-vessels, and especially the lymphatics of anterior surface, very much distended.

The taste goblets of posterior surface very opaque, the individual cells indistinct. The whole goblet separated from the surrounding epithelium and mucosa by a clear space, *i.e.*, fluid.

The veins of posterior surface filled with fibrin. All the changes decrease in intensity towards the basis of the organ. The epithelium on the whole extent of both surfaces is laminated pavement epithelium.

The mucous membrane of the laryngeal entrance, *i.e.*, the false vocal chords, is covered with laminated pavement epithelium, more or less infiltrated with lymph cells. The mucosa contains numerous lymph corpuscles, amounting at many places to continuous masses of lymphatic tissue. In the ventriculus Morgagni the mucosa beneath the epithelium (ciliated columnar epithelium) is transformed into one plaque of lymphatic tissue, in which the individual lymph follicles are more or less distinctly defined. Some of the lymph follicles of the false vocal chords, as well as in the ventriculus Morgagni, show the central part transparent, *i e.*, changed in the manner described above. The tissue around the mucous glands, and also the intermuscular tissue, much infiltrated with lymph cells.

The epithelium of true vocal chord is very much infiltrated just at the edge ; it is nearly normal in the adjoining parts, and becomes again much infiltrated lower down in the larynx. In the region of cricoid cartilage the superficial layers of the epithelium are just as intensely infiltrated with lymph cells as in the pharynx or root of tongue. The mucosa contains many lymph cells, and in the lower parts plaques of lymphatic tissue.

In the lowest part of larynx the inflammation is still more intensive. There is hardly any trace of the normal columnar ciliated epithelium, some places being covered either by a single layer of oblong cells, or, in addition to these, one, two, or more layers of polyhedral cells, between which lie smaller or larger numbers of lymph cells. At some places the epithelium looks just like laminated pavement epithelium, the superficial layers of which are infiltrated with lymph cells.

There is a hyaline elastic basement membrane of a considerable thickness immediately beneath the epithelium. Distinct canals pass from the lymph-lacunæ of the mucosa through the basement membrane into the canals and lacunæ of the epithelium (*see* Fig. XXI.). The mucous membrane of these parts is filled with lymph cells ; so is also the tissue around mucous glands, in some portions of which the nuclei of the lining epithelium appear to be increased in numbers.

The trachea shows in the upper parts very much the same kind of changes as met with in the lower portion of larynx, *i.e.*, the epithelium is at some places so changed from the ordinary laminated columnar epithelium that the superficial cells are polyhedral, or flattened ; at other places the epithelium so changed is densely infiltrated with migrants, the basement membrane thickened, and penetrated by canals. The is filled with adenoid tissue ; this reaches in some parts such an extent that the mucous glands of the submucous membrane have entirely or for the greater part given way before it. A similar change as that observed on the epithelium of the free surface may be noticed also on that of some large ducts of mucous glands. The ducts of some of these are exceedingly large, and lined near their mouth with laminated columnar epithelium, the most superficial cells of which are ciliated like those on the free surface. (Verson : article "Larynx," in Stricker's Handbook). Now, the epithelial lining of some of these ducts, surrounded by hypertrophied adenoid tissue, is over a greater or smaller area changed into laminated pavement epithelium, in which are

ound smaller or larger cavities filled with migrants (*see* Fig. XXV. and s explanation).

Amongst the hypertrophied lymph-follicles are some which show the eculiar transformation of the central part containing large multi-uclear cells (*see* Fig. XXVII.).

Blood-vessels are distended and filled with blood ; the nuclei of the uscular coat of arteries proliferating.

Case 4.—We shall be able to be very brief with this and the following ases, as we have described the general nature of the inflammatory hanges of the larynx and trachea so extensively in the preceding ase.

The changes of the epiglottis in this case are precisely the same as in ase 1, with regard to the inflammatory condition of the epithelium including the epithelial defect near the free edge of the organ), and the ypertrophy of the adenoid tissue of the mucous membrane of posterior urface—in some parts, the mucous glands have been replaced by it to a maller or larger extent. The mucous membrane of the anterior urface is more inflamed in this than in the former case.

The inflammation is likewise considerable in the mucous membrane of he larynx : false and true vocal chords and ventriculus Morgagni ; it is ery slight in the lower region of the cavity of the larynx, and increases gain somewhat in the upper part of trachea without, however, reaching he degree we noticed in the trachea of the previous case.

Case 5.—Epiglottis shows a considerable amount of inflammation ; pithelial defects near the free margin as well as near the basis, epithe-ium and mucosa in general much changed ; on the posterior surface lymphatic follicles very much hypertrophied and fused, so as to form continuous plaques.

The mucous membrane of the rest of larynx shows only slight though distinct signs of inflammation. Especially noteworthy is the fact that in some parts, *e.g.*, false vocal chords and lower region of larynx, *i.e.*, the region of cricoid cartilage, the mucous glands become entirely or to a greater or lesser extent lost as it were by the overgrowth of the lymphatic follicles of those parts. A similar state exists also in the trachea, in which the inflammation is otherwise only slight.

Case 6.—Epiglottis on both surfaces much inflamed. Epithelial defects on the posterior surface near the free margin of the organ. The lymphatic follicles of the posterior mucous membrane very much enlarged and fused into continuous masses. In some of them the greater transparency of the central part—containing the multinuclear large cells repeatedly mentioned—is conspicuous. The epithelial lining of some of the mucous ducts embedded in the lymphatic follicles of posterior surface contains larger or smaller cavities filled with migrants, similar to the cavities described in the epithelial lining of the mucous ducts of trachea of Case 1.

The mucous membrane of the cavity of larynx in general shows a moderate degree of inflammation. This becomes somewhat increased in the region of the first ring of the trachea ; here the epithelium has changed into laminated pavement epithelium more or less infiltrated with migrants ; the basement membrane appears much thickened, and the mucosa filled with numbers of lymph-cells. The same changes may be observed in the trachea ; in many parts the ciliated epithelium being completely replaced by laminated pavement epithelium ; the superficial layers of the epithelium are infiltrated with lymph-corpuscles, and are in the state of being detached—desquamating ; the mucosa filled

with lymph-cells; these are found also in great numbers around the mucous glands.

Case 9.—Very intensive inflammation of the epiglottis, especially of the mucous membrane of the posterior surface: epithelium of this part altogether gone near the margin of the epiglottis, and also the superficial parts of mucosa at some points ulcerated. Great increase of lymph-follicles of the mucous membrane of the posterior surface. The mucous glands are in a state of destruction.

The inflammation is considerable also on the mucous membrane of the anterior surface. A similar condition is present in the mucous membrane of the false vocal chords.

In the rest of the larynx, the inflammation is considerable, and it is greatest just at the boundary of larynx and trachea, the epithelium at these parts being altogether destroyed through the intensity of the process. In the whole length of the trachea, the hyperæmia of the mucosa is very conspicuous, this (mucosa) being of a deep red-brown colour, owing not so much to the excessive distension and filling with blood of the superficial vessels as to the mucosa being soaked with blood colouring matter. The mucous glands are much infiltrated with lymph-corpuscles, their epithelium opaque and in some places breaking down. The lymphatic follicles enlarged.

Case 11.—Inflammation of epiglottis considerable, it is exceptionally more intensive on the anterior than on the posterior surface. The mucous membrane of the larynx in general shows inflammatory changes of no great intensity. The following facts are conspicuous; (*a*) the excessive thickening of the epithelial lining of the ducts of mucous glands, and also of the corresponding portions of the surface, the epithelium having changed in both places from columnar into pavement epithelium composed of very numerous layers. The epithelium of the ducts is not uniformly thickened, its layers being generally unequal on numbers of different sides of the wall, as is well seen in sections in which the duct is cut transversely as in Fig. XXVI.; (*b*) the basement membrane underneath the laminated pavement epithelium of the true vocal chord is swollen up into a bulky glassy mass, so is also the subjacent elastic tissue of the mucosa, having changed into a dense reticular mass of a hyaline tissue.

In the trachea, the inflammation is distinct, though only slight; it increases in intensity in the larger bronchi.

Case 20.—Moderate degree of inflammation of epiglottis, false vocal chords, ventriculus Morgagni and true vocal chords, comprising the ordinary changes of vessels, epithelium and mucosa. Immediately below the edge of the true vocal chords there is an extensive defect, ulceration of the superficial part of the mucosa; this contains great numbers of spherical or oblong lumps of micrococci penetrating for various extent into the depth of the mucosa. (They are easily recognized in preparations stained in hæmatoxylin by their being stained deeply blue, caustic potash leaves them untouched while dissolving all the rest). The tissue underneath the ulcerated surface is infiltrated with fibrinous material. It is of interest to notice that the epithelium of the mucous membrane of the larynx next the ulcerated part is changed from ciliated columnar into pavement epithelium consisting of a great number of layers; the same is the case with the epithelial lining of the mucous ducts. In the latter it is very conspicuous. The same condition obtains very nearly up to the lower edge of larynx. The mucous membrane is slightly infiltrated with lymph-cells. The blood vessels distended and filled with blood and fibrin. The nuclei of the

lothelium of veins very markedly increased in numbers. The ucous membrane of the trachea shows very little change, the epi- elium containing very numerous goblet cells filled with mucous.

Case 22.—The epiglottis shows very intensive inflammation, the super- ial parts of the mucous membrane of both surfaces being ulcerated many points. The mucous membrane down the larynx is slightly iflamed with regard to the epithelium and mucosa. The inflammation most marked in the beginning of trachea, where the epithelium has changed that it consists of several layers of polyhedral cells. he mucosa contains great masses of adenoid tissue. The mucous ands show, however, very little change. Lower down the mucous embrane is only slightly changed ; the epithelium contains very merous goblet cells filled with mucous.

(B.) *General Remarks on the Changes of the Organs of the Throat.*

If we now summarise the results of the microscopic examination of ie organs of the throat we arrive at the following conclusions :—

1. With reference to the tongue, palate, tonsils, and pharynx : in vidence of acute inflammation we have distended blood-vessels filled ore or less with fibrin, leucocyte-infiltration of the mucosa, especially ound the veins and capillaries ; leucocyte-infiltration of epithelium, rticularly near the surface ; nuclei of epithelial cells in a state of rmination, with their nucleoli in some instances exceedingly large, ngular, double, or even multiple. On account of the presence of these hanges the corresponding strata of epithelium become gradually trans- rmed into a sort of honeycomb-structure, in which the outlines of the pithelial cells are indistinct or lost. At the same time it is to be bserved that the more intense the leucocyte-infiltration of the superficial trata of the epithelium the more distinct is the exfoliation or peeling of hose transformed layers.

The interstitial substance of the epithelium is very distinct, trans- arent, resembling broad clear canals, which at some places appear to ave become distended to small lacunae ; through these canals or rather ntercellular passages—they are probably only a fluid albuminous sub- tance easily permeable both by fluid as well as formed parts—migra- ory cells find their way from the mucosa into the superficial layers of he epithelium. These interstitial canals are most marked on the ungiform papillae of tongue owing probably to the considerable swell- ng of these structures, attributable not so much to infiltration with ymph-cells as to exudation of plasma.

Then we have the proliferation of nuclei of the endothelium of blood- essels, and likewise of the sheath of nerve-trunks, of muscular coat f arteries and the very conspicuous linear accumulation of nuclei in triped muscle fibres.

An interesting change is to be observed in some of the enlarged ymphatic follicles of the root of tongue and tonsils, consisting in the radual disappearance of the ordinary small lymph corpuscles with their mall circular deeply-stained nuclei from a greater or smaller portion of he centre—extending in most cases over more than half the diameter of follicle—and the appearance of larger transparent cells with ovoid ransparent nuclei. This gives to the follicle a very characteristic aspect ; he peripheral part which is composed of densely-crowded small lymph- ells with round deeply-stained nuclei appears in hæmatoxylin prepara- ion of a deep purplish-blue colour, which contrast very conspicuously vith the transparent only very slightly stained central portion. The

cells in in this latter are more or less granular, and of very different sizes; their outlines are never very distinct; they are, however, tolerably clear as long as they are small; when they have grown large they appear like flat transparent masses of very indefinite outline; their nuclei are as mentioned already, sharply defined, transparent, with one or more nucleoli, oblong or slightly irregular; the smaller cells have one nucleus, or a nucleus in state of division or already divided, or they have more than two nuclei; the largest cells have up to 30 and perhaps more nuclei. In some of the follicles the central part is composed only of large multinuclear cells, between which there are here and there a few of the smaller kind, and one or the other small lymph-cell.

Now the important question presents itself, what is the nature, origin, and fate of these cells? From the general character of these cells and their nuclei it is highly probable that they are endothelial elements, *i.e.*, flattened cells, with an ovoid transparent nucleus, which, as I have—in harmony with Bizzozero—pointed out in my paper on the Anatomy of Enteric Fever, (*see* these Reports, 1875,) in connexion with the lymphatic-follicles of the intestine, are placed on the adenoid reticulum, and are different from the lymph-corpuscles situated in the meshes of that reticulum. At the same time as the endothelial elements of the adenoid tissue increase in size, their nuclei undergo repeated division, and the ordinary lymph-cells of that tissue gradually disappear, until a condition is produced like the one represented in Fig. XXVII.

In some of the follicles it does not proceed to the formation of large multinuclear cells, for the enlarged endothelial elements having previously become slightly yellowish degenerate into a colloid substance, in other cases they change into fibrous masses. This we shall meet to a great extent in the cervical lymphatic glands, of which more hereafter.

In my paper on the Anatomy of Enteric Fever a similar change has been described of lymphatic follicles of the intestine, viz., the centre of some follicles becoming more transparent and showing chiefly enlarged endothelial cells, which are gradually transformed into multinuclear masses (*see* Fig. XLIV of that paper); in the case of typhoid fever these multinuclear masses were in some instances very regular "giant cells" of more or less cylindrical shape, the nuclei of which were chiefly distributed along the periphery (*see* Fig. XLV of the same paper). Like in the case of the lymphatic follicles of the intestine in enteric fever so also in that of the lymph follicles of the tongue and tonsils in scarlatina, there are apparently two kinds of processes going on, viz., one process in the course of which the overproduction of lymph cells leads to a destructive change, *i.e.*, to sloughing, suppuration, and another in the course of which the ordinary lymph cells disappear from a greater or smaller part of the follicles, and are replaced by large multinuclear cells derived from the pre-existing endothelial cells of the adenoid tissue. It is very probable that these cells show active changes only so long as their nutrition is not impaired either by mutual interference, *i.e.*, pressure in consequence of increased size, or by compression and obliteration of blood-vessels.

There is one more subject I wish to say a few words about. It is with reference to the ulceration of soft palate and pharynx and the suppuration and sloughing of the tonsils. It is an interesting fact that the ulceration of the soft palate is chiefly developed on the upper surface, and similarly also the pharynx when ulcerated is ulcerated chiefly in the part nearest the nasal cavity. With reference to the lumps of micrococci which we mentioned in connexion with the ulcerated parts of soft palate pharynx and tonsils, either of the following considera-

tions may suggest itself; (*a*) the micrococci may be of no other import than septic micrococci, which are thriving on an ulcerated surface, an occurrence not unknown in the pathology of ulcerations of mucous membrane; (*b*) or they may be indicative of diphtheria; or (*c*) they may be belonging to the proper scarlatinous affection. The second is not likely, for the reason that there were no diphtheritic membranes to be observed with the naked eye in any of the cases which I examined, the ulcerations being chiefly microscopic defects in an highly inflamed mucosa, whereas the first cannot easily be disproved, for the simple ground that the lumps of micrococci were found chiefly on the surface of the ulcerated parts, whence they extend into the adjacent parts which are in the act of breaking down. We mentioned their presence in the débris of a lymphatic follicle of the tonsil, which in the microscopic section appeared to be some distance from the surface, but it cannot be proved that those micrococci are not directly or indirectly connected with the free surface of the organ. If therefore on the one hand it appears probable that the lumps of micrococci found in the ulcerated and sloughing parts, connected with the free surface, have no specific significance, the possibility is not altogether excluded, that they stand in some connexion with the scarlatinous process. MacKendrick observed (British Medical Journal, 1875), micrococci on the mucous membrane of the inflamed throat in scarlatina, he is inclined to attribute to them a specific character. This I think cannot be done with safety so long as there is another and simpler explanation for their occurrence.

It is probable that all the morbid changes in scarlatina play an important part in the distribution of the contagion, no matter whether they arise in the skin, throat, lymphatic glands, or other organs, inasmuch as the morbid processes in these different organs are the result of the action of the specific virus. We have here specially in view the fact that the epithelium of all the organs of the throat, tongue, pharynx, palate, and, as we have seen, also the mucous membrane of the larynx and trachea, is charged with inflammatory products, and that its superficial layers, which in many parts are especially rich in those products, are being cast off in a smaller or larger quantity, not to speak of those parts where the tissue in consequence of suppurative changes is altogether breaking down into a débris. The contagiousness cannot be referred to the skin alone, for the desquamating epithelium of the skin and the material which is shed from the organs of throat are of one pathological category.

I tried a few experiments of inoculating guinea-pigs with the muco-products of the organs of the throat of Case 5, obtained very soon after death, but these experiments gave no other results than (in some cases) such as might be ascribed to common septic inoculation.

(2.) With reference to the larynx and trachea there is very little to be said different from what has been said with reference to the pharynx and palate. All parts of the larynx show inflammatory changes, which at some points—as epiglottis and lower margin of larynx—are more intensive than at others, amounting in some cases to ulceration; also the trachea is slightly inflamed. Besides the ordinary symptoms of inflammation, the following appearances deserve special notice: (*a.*) the changes of the epithelium in some parts of the larynx and trachea, the epithelium having, namely, changed from columnar and ciliated into laminated pavement epithelium, which may desquamate to a greater or smaller extent; in some parts the increase of the thickness of the epithelium of the surface as well as of that lining the ducts of mucous glands is very great; (*b.*) the hypertrophy of the adenoid tissue of the posterior

surface of epiglottis, false vocal chords, ventriculus Morgagni, and trachea; in some of the hypertrophied lymph follicles the same changes are observed as in those of root of tongue and tonsils, *i.e.*, the central part contains large multinuclear cells, very few ordinary lymph-cells, and is much more transparent as compared with the peripheral portion; (*c.*) the partial or total destruction of mucous glands by the hypertrophied lymphatic tissue; the epithelial lining of mucous ducts surrounded by lymphatic tissue shows distinct signs of proliferation, being at the same time penetrated by lymph-cells, which accumulate in small cavities.

V.—Examination of the Alimentary Canal.

Of the alimentary canal, the œsophagus has been examined in cases 1, 5, 6, 9, 11, 20, and 22; the stomach, the small and large intestine in Cases 9 and 11. To these I have to add the lower part of ileum that I had examined about two years ago of a case that died in a very early stage of scarlatina, I believe in the middle of the first week; the mucous membrane of the lower part of ileum of this case was studded with numerous whitish papules of the size of a millet seed.

1. *Œsophagus.*

The œsophagus was in all cases slightly inflamed: infiltration with lymph-cells of the subepithelial mucosa and the epithelium itself, and distension of blood-vessels. The inflammation is, as a rule, most marked in the upper part next the pharynx, but in some cases it is quite as intensive in the lower portion of the œsophagus as in the pharynx, *e.g.*, in Cases 6, 9, 11. The intensity of the inflammation varies in the different cases; whereas, for instance, in some cases, 5 and 20, the chief symptom of inflammation besides the condition of the blood vessels, is the infiltration of the sub-epithelial mucosa, the epithelium itself showing only slight changes—a few migrants amongst its cells. We find in other cases not only a very considerable infiltration of the mucosa with lymph-cells, but also very great numbers of migrants in the superficial layers of the epithelium, which at the same time shows signs of proliferation in the deeper layers, and distinct desquamation of its surface strata. In Cases 1, 9, 11, and 22 the inflammatory change amounts at some parts to partial or even total destruction of the epithelium, and to breaking down of the most superficial part of the mucosa—ulceration. The mucous glands situated in the submucous tissue appear little affected; only in Case 6 have I seen the epithelium of some parts of the glands opaque and swollen, or disintegrating into granular matter.

The walls of veins as well as arteries were distinctly thickened in Case 20 owing to an increase of the nuclei of the endothelium as well as of the muscle fibres.

2. *Stomach.*

In Case 9.—The stomach of this case was very well preserved. The following changes were observable: the epithelium was detached and gone from the surface of a few folds. The epithelium lining the gland tubes is in some instances found to be loosely attached to the membrana propria, and even becoming discontinuous. At the bottom of the gland tubes the epithelium is detached from the membrana propria, but the lumen of the tube is still distinctly preserved.

The tissue surrounding the basis of the glands is filled with very numerous lymph-cells, that is to say their number being much greater

than in the normal condition. In some of the large arteries of the submucous tissue the nuclei of the muscle fibres are distinctly proliferating.

In Case 11.—The epithelium of the surface and the ducts of glands is breaking up into small granular elements, the epithelial lining of the deeper parts of the gland-tubes is seen to be more or less detached from the membrana propria, and in some instances is breaking up into its elements. The veins and capillaries filled with blood. The nucleated septa extending from the membrana propria between the individual cells lining the gland tubes are very distinct, thick and deeply stained in logwood preparations. The tissue of the mucosa (between the gland tubes) is swollen up into hyaline structures. This last fact indicates that the wall of the stomach had probably been subject already to post-mortem digestion, and that therefore the condition of the epithelium of the surface and glands has probably not been existing during life.

My observation of the well-preserved stomach (Case 9) differs from the cases observed by Fenwick. This author says (l. c., p. 101): "The first effects of the scarlatina poison upon the "stomach seem to be to congest the blood-vessels and to strip the "epithelium from the tubes and the surface of the organ, at the same "time that the tissues are softened. The tubes are greatly distended "with granular and fatty matters or with cells intermixed with granules; "whilst in other cases they are lined by a newly-formed membrane. "Sometimes no normal cells can be distinguished, in other cases they "are present, but are scattered irregularly."

(3.) *Small and Large Intestine.*

In Case 9.—The duodenum shows the following changes: the epithelium covering the villi loosened or entirely detached, whereas that lining Leiberkühn's crypts is in many instances breaking up into the individual cells, which are for the most part transformed into goblet-cells. In Brunner's glands the epithelial cells lining the secreting parts are swollen and transparent; in some tubes they are detached from the membrana propria, isolated, and lie scattered about all along the cavity of the tube, being at the same time transformed into goblet-cells each with a round transparent nucleus at the pointed extremity. In the ileum we meet with the same condition of the epithelium covering the villi as well as that lining Leiberkühn's crypts. The tissue of the mucosa between the crypts is increased in amount owing chiefly to the increased number of lymph-cells.

In the lower part of ileum the mucous membrane contains structures identical with lymph follicles, forming a nodular swelling projecting more or less over the free surface. [When looking at the internal surface of the ileum with the unaided eye those swellings were recognizable as smaller or larger papules raised slightly over the general surface of the mucosa—a condition very well known to pathologists.] In my paper on the Anatomy of Typhoid Fever (see these Reports, 1875, p. 91) I have pointed out that the papular swellings observable in the lower end of ileum in that form of the disease called by French writers "la forme bontonneuse" is not, as has been always supposed, due to hypertrophy of pre-existing solitary lymph-follicles, but only partly so, for a portion of them owe their origin merely to a local increase of the pre-existing adenoid tissue, of which the mucosa is composed. The same relation I maintain also for the papular swellings observed in the ileum of this case as well as of that other case which I mentioned in the commencement of this chapter as having been examined by me about two years

ago, viz., that some of them are due to a hypertrophy of solitary lymph follicles, others to that of the pre-existing adenoid tissue of the mucosa.

With regard to the cœcum we find: loosening and detachment of epithelium of the free surface, detachment from the membrana propria, and even breaking up of the epithelium lining Lieberkühn's crypts into small cells which are at the same time transformed into goblet-cells; the lymphatic follicles are enlarged, and show a transparent centre containing large transparent cells with one, two, or more oval transparent nuclei—a condition similar to that described of the lymphatic follicles of the organs of throat.

In Case 11.—The conditions prevailing here are much the same. In the duodenum we find: epithelium of many villi gone; where it is left its cells are either very opaque or they are transformed into goblet-cells; in some parts also the tissue of the villi appears to be breaking up. Dark pigment granules are found in the cells of the villi. The mucosa is much hypertrophied; the epithelium of Lieberkühn's crypts is very opaque and granular, many cells are goblet-cells, the lumen of the crypts is, however, distinct and empty. At the mouth of the crypts the epithelium is missing; the epithelium-cells lining the tubes of Brunner's glands are either goblet-cells or altogether gone, and in their stead the tube contains a slight amount of granular matter; the lymph follicles are much enlarged, all of them showing the transparent centre, containing large hydropic cells; the blood-vessels distended and filled with blood; the serous covering and the connective tissue in the external longitudinal muscle-coat is much swollen and almost hyaline.

In the ileum: the epithelium covering the top of villi is either raised and separated from the subjacent tissue by cavities containing cells and granular matter, or is altogether broken away. The epithelium lining Lieberkühn's crypts is not changed. In a few places there are swollen lymph follicles with transparent centre; the blood-vessels of the submucous tissue are filled with blood. In the lower part of the ileum the swelling of lymph follicles is very great, and the difference between a central and peripheral zone can readily be recognised with the unaided eye on preparations stained in hæmatoxylin: the increase in number of the nuclei of the endothelium in minute blood-vessels of these lymph follicles is very marked.

The condition of the cæcum and processus vermiformis is similar to that of the last-named case. Epithelium of the surface, and at the mouth of the Lieberkühn's crypts is loosened, and in some places altogether missing; that lining the crypt itself is only slightly more granular, otherwise normal. The mucosa is more numerous in lymph cells than normally. The lymph-follicles are enlarged. In the processus vermiformis they show very well the transparent central portion.

Thus we find in the intestine in general changes due to slight degrees of catarrhal inflammation and œdema: loosening and breaking down of epithelium of different parts, and increase of cells of the mucosa, the lymphatic follicles of some parts (duodenum, ileum, and cœcum) are enlarged, and their central portion has undergone the same change as described in those of the throat, *i.e.*, disappearance of ordinary lymph cells from the central portion, and the presence of enlarged transparent cells with one, two, or more nuclei. The duodenum appears to be mostly affected.

Here again my cases do not quite tally with those of Fenwick, who found (l.c., p. 101) that "the effects of inflammation (sc. Scarlatina) "upon the intestine seems, in slighter degrees, to consist in the effusion of "granular and fatty matters into the mucous membrane; but in more

"severe cases the tubes of Lieberkühn are often choked with epithelial "cells, whilst extravasation of blood takes places in the villi; and these "with the rest of the mucous membrane are loaded with small cells "and granules. In one case the villi were completely destroyed, and "the tubes of Lieberkühn were greatly enlarged and distended by cells "and granular matter."

That the mucous membrane of stomach and different parts of intestine are sometimes affected with a much more or less distinct catarrhal inflammation, and that the lymphatic follicles are in some instances enlarged, is well known. *See* E. Wagner, l.c., and Thomas in Ziemssen's Cyclopædia, p. 227.

With reference to the lymphatic follicles of the intestine, John Harley, [The Pathology of Scarlatina &c., Medico, Chirurgical Transactions, second series, volume 37, 1872] has made extensive studies—40 cases—in their gross anatomical relation. He finds (p. 123 and 124): "The "solitary glands of ileum were forming white granular or papular solid "feeling elevations, giving the mucous membrane the appearance of "being thickly sprinkled with grains of sago in 14 cases. In others "the solitary glands were only partially affected, the swelling being "usually softer and more diffuse, and the glandulæ deeply injected." In four cases the glands were unaffected "The solitary glands of "large intestine were enlarged and inflamed in several cases. In one "of them there was acute desquamation of the mucous membrane "of nearly the whole of the large intestine. In another case the "cæcum was severely conjested." In half of the cases no alteration was to be observed in the solitary glands of large intestine.

"The agminated glands were more or less swollen and inflamed in "every case but one."

VI.—Examination of Salivary Gland, Pancreas Gland, and Liver.

The salivary gland (submaxillary gland) has been examined in Cases 5, 9, and 22; the pancreas in 9 and 11; whereas the liver had been studied in Cases 1, 4, 5, 6, 9, 11, 20 and 22.

1. *Salivary Gland.*

In Case 5.—The epithelium of small ducts detached from the membrana propria, the lining cells of most alveoli granular and their outlines not well marked. The most important change, however, is presented by collections of lymph cells in the connective tissue supporting the ducts and larger blood-vessels. They each possess one nucleus and form at some places not well-defined infiltrations, and are apparently in connexion with the large venous vessels. In some of the large ducts is contained the same kind of glistening amorphous or globular (lime) matter which we met with in the tubes of kidney in some of the above cases; in this case also it stains deeply blue in hæmatoxylin, and is soluble in dilute hydrochloric acid.

In Case 9.—The collection of lymph-cells in the lobular septa is very conspicuous, they are chiefly around veins. The lymph spaces in the lobules are very distinct, being in a distended condition. The blood-vessels are filled with blood. The nuclei of muscle fibres of arterial coat are in a state of proliferation.

In Case 22.—We find the same condition as in Case 5, with the addition that the collections of lymph-corpuscles in the connective tissue is not limited to the part around the veins, but appears to be connected also with the large ducts.

This condition, *i.e.* the collection of lymph cells in the connective tissue surrounding the veins and ducts, is to be regarded therefore probably as a constant feature, occurring as it does in cases of very different periods, as in Case 5, after an illness of four days' duration, in Case 9, five, and in Case 22, twenty-six days.

2. *Pancreas.*

In both cases—9 and 11—in which this gland had been examined the changes were found to be only slight, they are as follows: The epithelial lining of many alevoli detached from thier membrana propria, and in a few instances the epithelium was found breaking up into small nuclear granular elements, scattered irregularly through the cavity of the corresponding alveoli. The blood-vessels are distended, and the lymphatic vessels of the interlobular septa are very distinct. There are small collections of lymph corpuscles in the connective tissue around large ducts.

Fenwick (l.c.) also found the pancreas in a slightly inflamed condition.

The symptom of collections of lymph-corpuscles in the connective tissue around the larger veins and ducts, which we meet with so constantly and conspicuously in the salivary glands, and also to a certain extent in the pancreas, is still more highly developed in the liver, as is shown in the following cases.

3. *The Liver.*

Case 1.—The liver slightly enlarged. The liver cells in general granular, opaque, and swollen, so that their outlines are not very distinct. In some parts the liver cells are filled with small fat globules. The walls of intralobular capillary vessels opaque and granular, and between these and the trabeculæ of liver cells we find large granular flattened cells with an oblong clear nucleus. There can be little doubt about these being the enlarged intralobular connective-tissue cells. The chief feature of interest, however, is the presence of numerous lymphoid-corpuscles in the interlobular connective tissue. These cells are of two kinds; (*a*) ordinary round lymph cells generally with one round nucleus, in a few instances with two small nuclei staining deeply in hæmatoxylin; and (*b*) larger granular cells with a large ovoid clear nucleus and nucleolus. In some of the last-named cells the nucleus is divided or is in the act of division. These cells form more or less dense accumulations between the bundles of the interlobular connective tissue. The greater the number of these cells the thicker appear the interlobular septa. These cells are seen to be most numerous around the bile ducts. The collections of cells are in some places so numerous that they form continuous masses, and hence the interlobular tissue appears much thickened over larger or smaller sections of the liver. The adventitia of the very large bile ducts contains also numerous lymph cells, and the lining epithelium is infiltrated with small cells similar to colourless blood corpuscles; very often the epithelium is detached from the membrana propria and disintegrating. The last-named fact may be observed also in small bile ducts.

The arteries are distinctly thickened, the nuclei of their muscular coat increased in numbers; in some of them the intima at some points shows the same hyaline degeneration noticed in the kidney.

Case 4.—The following are the changes to be noticed in this case:—(*a.*) The liver cells next the central intra-lobular vein are opaque, they are smaller and their edges are rounded off, *i.e.*, they are loosely con-

nected with each other, some are even breaking up into granular fragments. In some places the liver-cells are filled with fat droplets. At some parts the intralobular lymphatic spaces, *i.e.*, those between liver-cells and capillary blood-vessels, are very marked, being distended, and the intralobular connective tissue cells lying in those spaces are like those in the preceding case, enlarged and granular. (*b.*) The nuclei of the muscular coat of arteries are much more numerous than under normal conditions, the interlobular veins contain much fibrin and numerous colourless corpuscles. The nuclei of the epithelium of minute bile ducts are more numerous than normally, and in some instances are seen in state of division. In some small bile ducts the epithelial lining is seen to be detached from the membrana propria. (*c.*) The interlobular connective tissue shows the same accumulation of cells as in the former case, and the infiltration with lymphoid cells is encroaching already on the periphery of the acini themselves.

Case 5.—In addition to the changes mentioned in Case 4 there is in this case thickening of the capsule of the liver at some places owing to the presence of numerous lymphoid corpuscles between its connective-tissues bundles.

Case 6.—The liver is slightly enlarged. The liver-cells next the central intralobular vein contain pigment granules. All the other changes are the same also in this case, viz., the changes referring to the liver cells, the intralobular lymph spaces, the intralobular connective-tissue cells, the blood-vessels and bile ducts and the cell accumulation in the interlobular connective tissue. This infiltration is very considerable, and is encroaching already on the peripheral parts of the liver acini.

Case 9.—The liver distinctly enlarged. The interlobular tissue is very much thickened over extensive portions of the liver, owing to the fact that the cell accumulations form continuous masses. The intralobular connective-tissue cells are very distinct and numerous, and besides them there are also a few small round lymph cells, so that we have at some places the same kind of cells as those in the interlobular tissue, viz., (*a.*) ordinary small round cells, and (*b.*) larger granular cells with an ovoid nucleus. All other changes are the same.

Case 11.—The cell-accumulation in the interlobular connective tissue is very slight in this case, but quite distinct. The liver-cells next the intralobular vein opaque, and in some instances filled with small fat-globules.

Case 20.—Considerable fatty infiltration of liver-cells in the peripheral portion of acini, whereas those near the intralobular vein are opaque, granular, and disintegrating into granular fragments. The interlobular connective tissue contains only small collections of lymph-cells.

Case 22.—The lymph spaces near the interlobular veins are very much distended, and the liver cells of the adjacent part opaque and smaller, their angles rounded off; occasionally they contain pigment-granules. The cell accumulations in the interlobular connective tissue are distinct but not very numerous. Veins and capillary blood-vessels in general distended and filled with blood.

Thus we see that the liver presents in all cases, earlier as well as later stages, the same important changes. The abnormal condition of the liver cells and the state of the blood-vessels are evidently not of so great an importance as the alterations of the inter- and intralobular connective tissue. The first is thickened owing to the accumulation of lymph-cells forming more or less continuous masses. It is no doubt

interesting to find that already after two and five days' illness the liver should present such masses of interlobular cell accumulations, as happened in Case 1 and especially in Case 9. The cells are of two kinds: large and small ones. The large ones which we described as granular cells with a single or a double oval clear nucleus are no doubt merely the enlarged connective-tissue corpuscles of the interlobular connective tissue, whereas the small ones with a round nucleus staining deeply in hæmatoxylin correspond to the ordinary round lymph cell. When the interlobular cell accumulations are already encroaching on the peripheral portion of the acini, these latter contain in addition to the enlarged connective-tissue cells also a few round cells.

It appears that in the later stages, Cases 11, 20, and 22, the cell-accumulation in the interlobular tissue is decidedly much slighter than in the earlier stages, and that also the changes of the liver cells are more marked in the later stages, thus proving that they are not dependent upon the interlobular condition.

This is what I find in the literature with regard to the interlobular cell-accumulation: E. Wagner (l.c.) found in the same case that was quoted on a previous page (*see* Kidney), *i.e.*, a case in which death ensued after 48 hours, the following conditions of the liver: the organ was of normal size, on its anterior edge were visible (with the unaided eye) numerous, on other places few very minute whitish granules; the same is observable on all cut surfaces of the liver. Under the microscope these white masses were seen to represent the same kind of new growth of lymphatic or adenoid tissue, which E. Wagner found in the liver and spleen in some cases of variola (Archiv der Heilkunde, V. Jahrgang, p. 90. The cells and nuclei representing that new growth were chiefly situated in the interacinous connective tissue, which appeared therefore much thickened. The liver of the scarlatina case contained "besides the microscopic "whitish masses, in addition numerous microscopic groups of cells "and nuclei, chiefly in the interacinous connective tissue. The liver "cells were nearly of normal size, but much clouded by albuminous "and fatty molecules."

In a second case of scarlatina,—boy of three years,—who died after 23 days in consequence of diphtheria, E. Wagner found the same condition of the liver, which was, however, distinctly enlarged.

In the case published by Biermer (l.c.) the liver was enlarged, and showed on microscopic examination "a very distinct meshwork of connec-"tive tissue with a few nuclei, in which the liver-cells were embedded. "The central portion of the acini surrounding a vein, the wall of which "is likewise somewhat richer in connective tissue, are yellow, owing "to a very marked accumulation of fat in the shape of smaller and "larger droplets, whereas more peripherally the cells are pale without "granular content, and are embedded in an increased connective tissue "network."

Although in this description of Biermer there is an increase of connective tissue undoubtedly to be recognised, still it is not of the same character as that in the two cases of E. Wagner. If I am to judge by my own cases I should be inclined to think that the new formation of cellular tissue is, as a rule, only distinct in the earlier stages of scarlatina, in later stages the cellular nature becoming more indistinct, the hypertrophied tissue having the character of fibrous connective tissue, as in the case of Biermer.

VII.—Examination of Lymphatic Glands.

The following lymphatic glands were examined:—

(*a.*) The lymphatic glands of the neck of Cases 1, 4, 5, 6, 9, 11, 20, d 22; (*b.*) the mesenteric glands of Cases 9, 11; (*c.*) the bronchial nphatic glands of Case 11.

All these glands were considerably enlarged and hyperæmic. Those the neck of course most, but in no case was there any suppuration them.

(*a.*) The lymphatic glands of the neck.

Case 1. The follicles and follicular cylinders are very much enlarged id their lymph cells easily shaken out; the fibres of the adenoid ticulum increased in thickness, and very many of the lymph cells of e adenoid tissue, as well as in the lymph sinuses are enlarged and ssess a transparent vesicular nucleus unlike that of the ordinary mph cells, which stains uniformly and deeply in staining fluids. The mph sinuses of the medulla contain numerous cells of very various spect and sizes, from ordinary small lymph cells, with one round nucleus eply staining in staining fluids up to large granular or transparent lls, with one or two oval transparent nuclei. In the cortical lymph llicles the contrast between the ordinary lymph cells and the enlarged ndothelial cells (see what has been said of lymph follicles in the organs f throat) is very conspicuous. (Compare Fig. XXIII.)

Some of the cortical lymph follicles show the same change of their ntral portion that has been mentioned repeatedly on former occasions, *c.*, the disappearance of the ordinary small lymph cells from the entral parts in which are present large granular cells with proliferating uclei.

The blood-vessels are excessively distended, and many veins filled vith fibrin. In the cortex the blood-vessels are all filled with blood.

The capsule and the connective tissue trabeculæ of the cortex are hickened by lymph cells, present in large numbers in them.

In some parts the cortical sinuses, and also at some points the eripheral portion of cortical lymph follicles are filled with what appears o be disintegrated cells, fibrin and granular matter.

Case 4.—The appearances are precisely the same as in the preceding ase, with this addition, that the lymph sinuses of cortex, and especially f the medulla, are much distended by large lymph cells,—some of them acuolated,—are filled with granular matter and fibrin. The thickened ibres of the adenoid reticulum, the enlarged lymph corpuscles, and the nlarged endothelial cells of the adenoid tissue, as well as the condition f the blood-vessels and the capsule, are the same as in the previous case. Numerous lymph follicles with transparent central portion.

Case 5.—The fibres of the adenoid reticulum are much thicker than normally; there are very numerous granular large endothelial-like cells n the cortical, and especially in the medullary lymph sinuses. In some portions they have become vacuolated. The blood-vessels are very listended, and in the cortical part they are filled with fibrin. The apsule and the trabeculæ are in many places much thickened by the resence of lymph corpuscles. The most important changes, however, re these: (*a*) there are follicles in which the central part has become ransparent owing to the presence of enlarged cells; these in some places nay be traced directly into huge granular giant cells, *i.e.*, masses of pherical or oblong shape, with a great number—20, 30, and more—of mall transparent nuclei, in this case chiefly disposed in the periphery of he cell substance (*see* Figs. XXVIII., XXX., and XXXI.), or they may

be seen to become very hard in their outlines, and assuming a more or less fibrillar character; (*b*) larger or smaller masses of a rigid fibrous tissue are found to take the place of the adenoid structure with nucleated remnants between them (*see* Fig. XXVIII. and XXIX.). The fibrous masses owe their origin in the first place to the swollen trabeculæ of the adenoid reticulum which afterwards become transformed into fibrous bands, both the lymph corpuscles between them and the enlarged endothelial plates fixed on them becoming gradually involved in the same fibrous degeneration. There can be little doubt that some of the larger giant cells give rise to smaller ones, as in Fig. XXVIII., but what eventually becomes of them, whether they also undergo fibrous degeneration or not, I am not in a position to say. A rather curious appearance is presented in a preparation which is copied in Fig. XXIX., viz., the presence of a huge giant cell situated in a focus of fibrous degeneration, in some parts of which the outlines of the enlarged cells are still visible; the giant cell is surrounded, as it were, by a thick hyaline glistening capsule. This cell is represented separately in Fig. XXX. as seen under a higher power; what appears as the capsule is seen to extend in the form of processes into the vicinity. It seems to me probably that what appears as the hyaline and glistening capsule (the fibrillation of it in the drawing is not natural, but is due chiefly to the defective execution) is not a capsule surrounding the giant cell, but is merely a part of the original adenoid reticulum greatly swollen up.

In Cases 6, 9, *and* 11 we meet with precisely the same changes as those described in Case 4.

Case 20.—Besides general enlargement of the adenoid tissue including the usual thickening of the fibres and the enlargement of the endothelial cells of the adenoid reticulum, the distension and filling of the lymph sinuses with various sized cells—some of them being vacuolated—the distended blood-vessels and the thickened capsule and trabeculæ, we find as in Case 5, the following changes: (*a.*) Transformation of the central portion of some lymph follicles into a transparent mass owing to the presence of enlarged cells; (*b.*) in some places this leads to the formation of huge multinuclear giant-cells; (*c.*) in others they degenerate, together with the adenoid reticulum of the neighbouring parts into a firm fibrous material, having swollen up previously into a hyaline mass. I have seen in several instances in the centre of the smaller, *i.e.*, younger foci of fibrous degeneration what appears to me to be a distended vein blocked up by a dense mass of fibrin and lymph cells.

Case 22.—This case differs from the preceding one in the following points: (*a.*) great increase of connective tissue in the capsule and trabeculæ; and (*b.*) the absence of giant-cells in those portions of the follicular tissue that have undergone fibrous degeneration. Otherwise the appearances are similar. Small masses of pigment are found in the tissue of the capsule and cortical lymph follicles.

Thus we may say that the enlargement of the lymphatic glands of the neck is due to an inflammatory increase of all the constituent parts of the gland,—including the filling and distension of the lymph sinuses with large cells and granular matter, which no doubt have been carried into the glands from the inflamed throat organs—and to the change of the lymphatic follicles noticed also in other organs (throat and intestine) which, however, in the case of the lymphatic glands under consideration leads to the formation of true giant-cells and to fibrous degeneration of the corresponding parts of the adenoid tissue. It is probable from the observations of Case 22 that also the giant cells become involved in the fibrous degeneration.

(*b.*) The mesenteric glands of Cases 9 and 11 were of precisely the same appearance. They were enlarged and showed the same structural changes as the glands of the neck, viz. thickened capsule and trabeculæ owing to the presence of lymph cells, distended blood-vessels, in many of them masses of fibrin. In the minute vessels the endothelial nuclei are distinctly increased in number. Lymph follicles and follicular cylinders much enlarged, the fibres of the reticulum thickened, and the endothelial cells much larger; the lymph sinuses are filled with cells of various sizes and their nuclei in state of division. There are lymph follicles in which the central portion has become changed into the transparent tissue composed of enlarged cells, and the same appearance may be noticed also in many lymphatic cylinders of the medulla.

(*c.*) The bronchial lymphatic glands, as well as those along the trachea of Case 11, were much enlarged and presented the usual appearances, including the peculiar change—transparent large and multinuclear cells—of the central portion of some lymphatic follicles; and in addition to this the lymph sinuses of some portions of the gland are greatly distended by clear plasma, in hardened specimens a very finely granular transparent material.

John Harley (l.c.) found the mesenteric glands generally and severely inflamed, the whole mesentery being thickened and the glands purple and swollen, in some cases to the size of a pigeon's egg; and Thomas (l.c. p. 227) states that "the mesenteric glands are 'generally found "hyperæmic and some of them considerably swollen and, when cut "into, their tissue is found to contain more fluid than usual."

VIII.—Examination of the Spleen.

The spleen was examined in Cases 1, 4, 5, 6, 9, 11, 20 and 22. The organ appeared slightly enlarged only in cases, 4, 6, 11, and 22.

Case 1.—The Malpighian corpuscles and the adenoid sheaths of arteries are very distinctly enlarged. The former show in many instances the peculiar change of the central part, containing large endothelial-like cells. Another noteworthy change consists in the hyaline degeneration of smaller or larger portions of the intima of arteries, leading at some places almost to total obliteration and degeneration of the wall of the vessel. In connexion with these changes we find the swelling up of larger or smaller portions of adenoid tissue around those arteries into hyaline or slightly granular masses, fibres and cells being completely lost in the said masses. There are, however, arteries in which the nuclei of the endothelium as well as those of the muscular coat, have undergone distinct proliferation. The walls of the large veins are much thickened by the presence of cell masses next the endothelial lining, which masses look exactly like adenoid tissue.

Case. 4.—The most interesting features in this case are the Malpighian corpuscles; not only are they much enlarged (as well as the adenoid sheaths of arteries in general) but they present, in preparations stained with hæmatoxylin, a very curious aspect when looked at with the unaided eye, or better with a lens. Each Malpighian corpuscle besides being enlarged appears to be composed of three distinct zones (*See* Fig. XXXV); (*a.*) a transparent yellowish centre; (*b.*) a deeply stained middle; and (*c.*) a slightly stained peripheral zone, gradually shading off into the surrounding parts. When examined with a low power the threee zones exhibit the following conditions:

(*a.*) The central transparent zone is, I need hardly say, due to the absence of ordinary lymph cells with the small deeply stained nuclei, and in their stead we find only large cells, with one or more transparent

nuclei, a condition with which we are quite familiar by this time. Most of these cells are slightly tinged yellow, owing to their containing several smaller or one large yellowish colloid-like droplet. (By contrast with the blue-stained median zone the central part appears only the more of a distinctly yellow colour.)

(*b.*) The median deeply blue stained region shows ordinary small lymph corpuscles, each with a small circular nucleus deeply stained, on account of the smallness of the cells and therefore close aggregation of the nuclei, this region appears very deeply stained.

(*c.*) The peripheral zone is less deeply stained than the preceding one and is composed of lymph cells each with one nucleus, but on account of the cells themselves being larger than those of zone (*b.*) the nuclei appear further apart from each other, and hence this zone is less stained than (*b*). In Fig. XXXVI a small portion of the central and the median zone has been copied, under a moderately high power (Hartnack's Objective 5). The wall of large veins thickened by what appears to be adenoid tissue, in the same manner as in the former case. Many arteries show the hyaline degeneration of the intima.

Case 5.—The same changes may be observed also in this case, with the difference only, that there are not so many arteries showing the hyaline degeneration as in the former case, and the Malpighian corpuscles are not so much enlarged, and their central portion not being degenerated so distinctly as in the former case.

Case 6.—This case is still more marked than Case 4, as regards the degeneration of arteries, the hyaline and granular degeneration of adenoid tissue and to the hypertrophy and change of Malpighian corpuscles, viz., as if composed of three zones. The degeneration of adenoid tissue, lymph cells and reticulum, mentioned in previous cases, is here seen to take place in connexion with the changed Malpighian corpuscles. The wall of large veins thickened.

Case 9.—The same changes, only of a slighter degree.

Case 11.—All the appearances previously mentioned are very well marked.

Case 20.—The number of arteries showing hyaline degeneration of intima, and the number of places where also the adenoid tissue is swollen up into a hyaline or granular degenerated substance, is considerable; so is also the thickening of the wall of the large veins.

Case 22.—The hyaline degeneration of intima of arteries may be observed in most arteries; in some instances the vessel appears quite obliterated, its whole wall having degenerated into a fibrous looking substance. The thickening of the wall of large veins by the presence of cellular tissue—very much like adenoid tissue—is greater than in any of the previous cases. The Malpighian corpuscles and adenoid sheaths of arteries are hypertrophied, the former showing the change of their central portion. Considerable masses of adenoid tissue have undergone the hyaline degeneration.

Thus we find, in the spleen of all the cases examined, the same changes occurring constantly, namely: enlargement of adenoid sheaths of arteries and of Malpighian corpuscles, and peculiar change of the centre of the latter; degeneration of arteries, and in connexion with it degeneration of the surrounding adenoid tissue; thickening of the wall of large veins, owing to the presence, underneath the endothelial lining, of cell accumulations very much resembling adenoid tissue. With reference to the above changes, their intensity stands, so it

ppears, in no relation to the stage of the disease, except in respect o the degenerative changes of the arteries, which in the later cases, 20 and 22, are undoubtedly more marked than in the earlier ones.

I need hardly add that the change of the Malpighian corpuscles is almost identical, at any rate of the same nature as the changes of the ymph follicles that we observed in the organs of the throat, and especially n those of the lymphatic glands; and likewise that the degeneration of adenoid tissue in the spleen is no doubt analogous to that observed in he lymphatic glands.

E. Wagner (l. c.) found the hypertrophy of the adenoid tissue in the pleen in both his cases, and Biermer (l. c.) found in his case the nlargement of Malpighian corpuscles very marked; "their constituent " elements, however, show no alteration."

EXPLANATION OF PLATES OF Dr. E. KLEIN'S REPORT.

Fig. I.—From a vertical section through epidermis of skin of case 2. Hartnack Ocular II., Obj. 5.

a. Rete Malpighii.
b. Stratum lucidum much thickened, and showing "granulation."
c. Stratum corneum.

Fig. II.—From Case 1. II., 7.

a. Rete Malpighii.
b. Cavity underneath the stratum corneum.
c. Filled with "granular" matter (*see* text).

Fig. III.—From a vertical section through epidermis of Case 18. (Desquamation) II., 8.

a. Rete Malpighii.
b. Stratum lucidum.
c. Stratum corneum.
d and *e*. "Granulation" contained in the desquamating parts. The lower edge of the "granular" lump, *d* is represented in the figure far too sharply.
f. Continuation of rete Malpighii on a sweat-duct.

Fig. IV.—Longitudinal view of a hair-follicle near its mouth, from Case 19. II., 7.

a. External root sheath.
b. Hair shaft.
c. Epidermis scales.
d. Thickened internal root sheath, containing "granulation."

Fig. V.—A similar preparation as Fig. IV. of the same case. II., 7. The meaning of letters the same as in IV.

e. Nuclei deeply stained.

Fig. VI.—From a preparation of kidney of Case 5. III., 9.

a. Arteriole in transverse section, most of the intima is swollen up into a hyaline mass, the nuclei of the muscular coat proliferating.
b. Section through a urinary tube (ascending tube of Henle), the nuclei of whose epithelium is much proliferating on the side nearest the arteriole.

Fig. VII.—From a similar preparation as Fig. VI.

a. Part of a glomerulus of Malpighian corpuscle.
b. Point of entrance of afferent arteriole into the glomerulus; the nuclei of artery much multiplied, and the intima in parts swollen up into hyaline blocks.
c. The urinary tube whose epithelial nuclei are much proliferating on one side.
d. Part of convoluted tubes.

Figs. VIII. and IX.—Malpighian corpuscles in process of degeneration into a hyaline or slightly striated substance.

a. Lumen of afferent arteriole.
b. Degenerated glomerulus.
c. Nuclei.
d. Thickened capsule.

Fig. VIII.—Is from Case 12, and drawn with II., 10, à immersion.

Fig. IX.—From Case 17, and drawn with II. 8.

Fig. X.—From kidney of Case 12. II., 7.

a. Afferent arteriole.
b. A portion of degenerated wall of the arteriole sliced off as it were, the artery having become at this point bulged out.
c. Point of entrance into glomerulus.
d. Glomerulus; nuclei of it much increased.
e. Bowman's capsule.
f. Convoluted tubes in section.

Fig. XI.—A Malpighian corpuscle greatly degenerated, from the kidney of Case 1. III., 7.

a. Lobules of glomerulus changed into hyaline masses containing nuclei.
b. Afferent arteriole.
c. Portion of glomerulus less changed than *a*.
d. Thickened and swollen capsule.

Fig. XII.—Degenerated Malpighian corpuscle, kidney of Case 12. III., 9.

a. Afferent arteriole, its wall much thickened.
b. Malpighian corpuscle.
c. Convoluted tubes in section.
d. Henle's tube.

Fig. XIII.—From the kidney of Case 17. II., 5.

a. and *b*. Degenerated Malpighian corpuscles.
c. Infiltration due to interstitial nephritis.
d. Urinary tubes in section.

Fig. XIV.—Malpighian corpuscle from the kidney of Case 18. H. II., 8.

a. Afferent arteriole containing an embolus; just at the point where the arteriole enters the glomerulus we find great increase of the nuclei of the artery's wall.
b. Space between Bowman's capsule and glomerulus; a few lymph corpuscles in it.
c. Infiltration with lymph corpuscles around the Malpighian corpuscle, and extending between the urinary tubes *d*.

Fig. XV. From a similar preparation of the same kidney. II., 5.

a. Interlobular artery, containing an embolus *e*.
b. Urinary tubes.
c. The same more or less filled with lymph-cells.
d. Malpighian corpuscle more or less degenerated. The tissue of this part much infiltrated owing to interstitial nephritis.

Fig. XVI.—From a vertical section through the kidney of Case 16. II., 5.

a. Large arterial, *v* large venous trunk at the boundary between cortical and medullary portion.
b. Convoluted tubes in section.
c. and *d*. Straight tubes of medullary rays.
i. Infiltration, *i.e.*, interstitial nephritis.

Fig. XVII.—From the kidney of Case 22. III., 7.

Portions of convoluted tubes, showing in 1 slight granular disintegration; in 2, fatty degeneration of epithelium.

Fig. XVIII.—Transverse section through small artery of epiglottis of Case 1. III., 7.

a. Lumen of artery.
b. Thickened muscular coat, showing in some parts multiplication of nuclei in muscle fibres.
c. Thin adventitia.

Fig. XIX. From a section through epithelium of a papilla of tongue, showing the intercellular canals, and migratory cells in them. III., 8.

a. Intercellular canals containing migrants.
b. Epithelial cells.

Fig. XX.—From a preparation of tongue, showing the infiltration of superficial layers of epithelium with lymph-cells, and division of nuclei of epithelial cells. III., 7.

Fig. XXI.—From a section through trachea; the ciliated columnar epithelium replaced by layers of polyhedral cells. III., 8.

a. Basement membrane; through it pass fine lymph-canals, which lead into distended interepithelial spaces *b.*, some of which contain migrants.
c. Migrants among the superficial epithelial cells.
d. Epithelial cells.

Fig. XXII.—From a section through tongue; showing the multiplication of nuclei of striped muscle fibres. III., 8.

Fig. XXIII.—From a section through tonsil; showing the multiplication of nuclei of unstriped muscle fibres of coat of a large artery. III., 8.

Fig. XXIV.—From a preparation of tongue; showing the multiplication of nuclei of endothelial wall of a distended vein. III., 7.

Fig. XXV. From a section through trachea; showing the epithelium of a large duct of a mucous gland; the columnar epithelial lining of a part of the duct is replaced by polyhedral epithelium, in which cavities have been formed of different sizes containing migrants. II., 7.

a. Epithelial lining of duct.
b. Cavities in the epithelium containing lymph-cells.

Fig. XXVI.—Transverse section through the duct of a mucous gland of false vocal chord, showing the great thickening of the epithelial lining. II., 5.

a. Lumen of duct lined by a layer of columnar cells; this is surrounded by several layers of polyhedral cells, among them a few (deeply stained) migrants.

Fig. XXVII.—From a section through trachea; showing a lymphatic follicle arranged in such a way that the central part shows only large granular multinuclear cell-masses; the periphery is composed of the ordinary masses of lymph-cells, whose number is, however, increased. II., 7.

Fig. XXVIII.—Giant-cells from lymphatic gland of neck; below *a.* the tissue is converted into a fibrous-looking material, including a few remnants of nuclei. III. 8.

Fig. XXIX.—Hyaline and fibrous degeneration of follicular tissue of lymphatic gland of neck.

a. A giant cell surrounded by a thick glistening homogeneous capsule. Round the giant cell are large swollen homogeneous or striated cellular masses. II., 7.
b. The tissue is already fibrous.
c. Lymphatic tissue of periphery.

Fig. XXX.—The giant cell of preceding figure more highly magnified II., 8.

a. Substance of giant cell finely and uniformly granular.
b. Hyaline capsule with two band-like processes, into which extends also the substance of the giant cell. The nuclei are situated in the peripheral part of the cell.

Fig. XXXI.—A giant cell of a lymphatic gland of neck. III., 8.

Fig. XXXII.—From a section through the cortex of lymphatic gland of neck (section had been shaken). III., 7.

a. Capsule of gland.
b. Cortical lymph sinus.
c. Lymphatic follicle.
d. Capillary blood-vessel.
e. Lymph-cells.
f. Large endothelial-like cells.

Figs. XXXIII. and XXXIV.—Arteries from spleen: showing the homogeneous swelling of intima. III. 5.

Fig. XXXV.—Malpighian corpuscle of spleen; showing three distinct zones.

a. Central part transparent, composed of swollen cells.
b. Intermediate zone, deeply stained in hæmatoxylin, because composed of dense accumulation of small nuclei of ordinary lymph-cells; and
c. Peripheral zone less deeply stained than *b.*, because composed of larger lymph-cells, the nuclei therefore less densely accumulated. II., 4.

Fig. XXXVI.—Showing a portion of *a.* central, and *b.* intermediate zone of Malpighian corpuscle under a higher power than in the preceding figure. III., 5.

Fig. XXXVII.—From the kidney of Case 21. III., 5.

a. Interlobular artery.
b. Infiltration due to interstitial nephritis.
c. An afferent arteriole degenerated.
d. Outlines of urinary tubes.

Fig. XXXVIII.—From the kidney of Case 19. II., 7.

a. Artery in transverse section, its muscular coat much thickened.
b. Sheath of artery completely resembling adenoid tissue.
c. Outlines of urinary tubes.

Fig. XXXIX.—Henle's tube from near the papilla in 1, the epithelial cells detached from membrana propria, large and granular, and containing lime-elements. In 2 it is still better seen that these last-named are contained within the epithelial lining. III., 8.

Fig. XL.—Interlobular infiltration of liver of Case 1. III., 4.

a. Bile duct.
b. Arteries, their wall much thickened.
v. Vein.
c. Lymph-corpuscles in the connective tissue; they are of two kinds: small deeply stained nuclei, and larger cells, the nuclei of which are large, transparent, oval or rounded.

Fig I

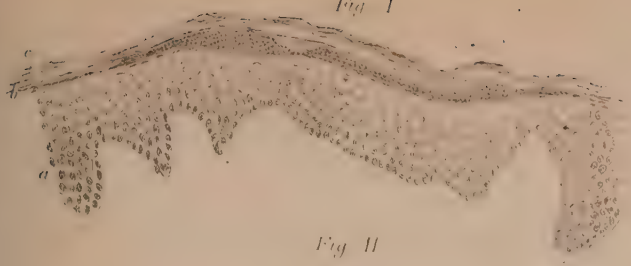

Fig II

Fig III

Fig. IV

Fig. V

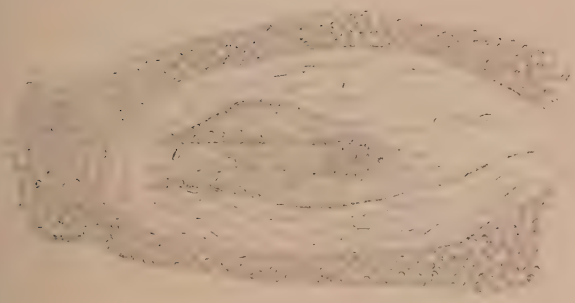

Fig. VI

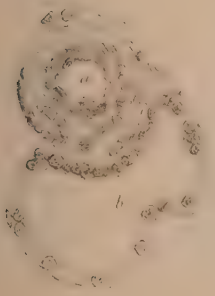

Fig. VII

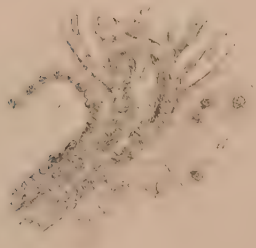

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Fig VIII.

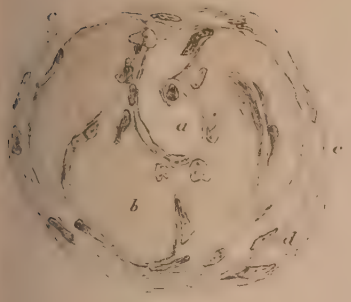


Fig IX.

Fig. X

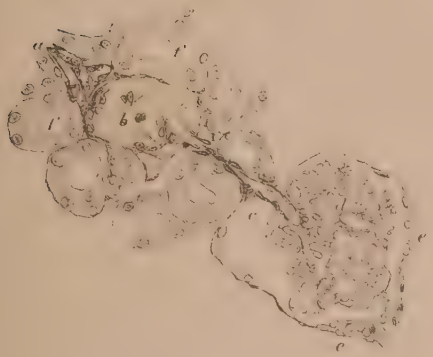
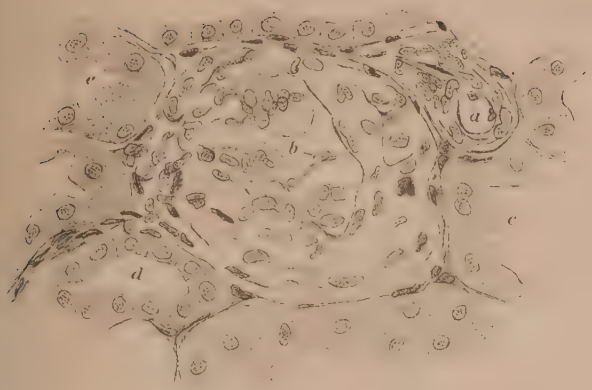


Fig. XI

Fig. XII



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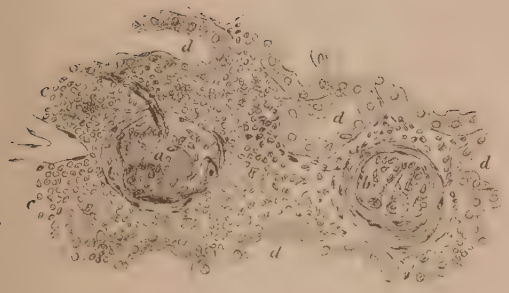

Fig. XIV

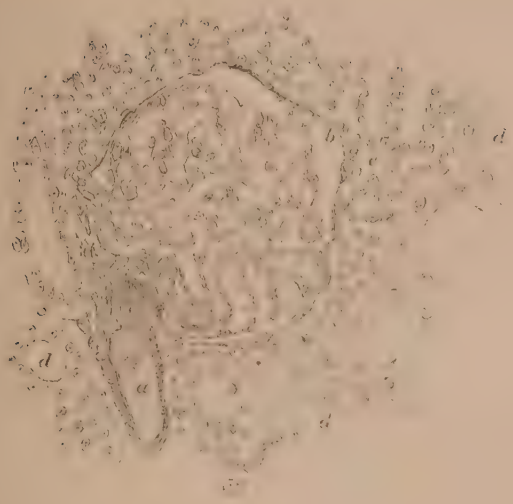

Fig. XV.

Fig. XVI

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Fig XX

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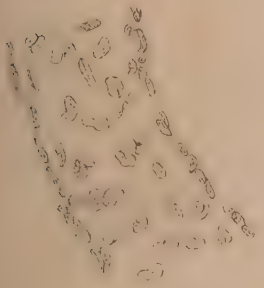

Fig XXIII.

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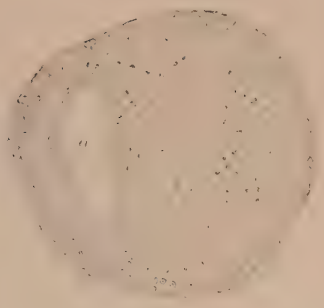
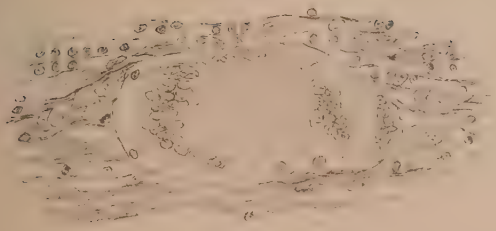


Fig XXVII

Fig XXVIII



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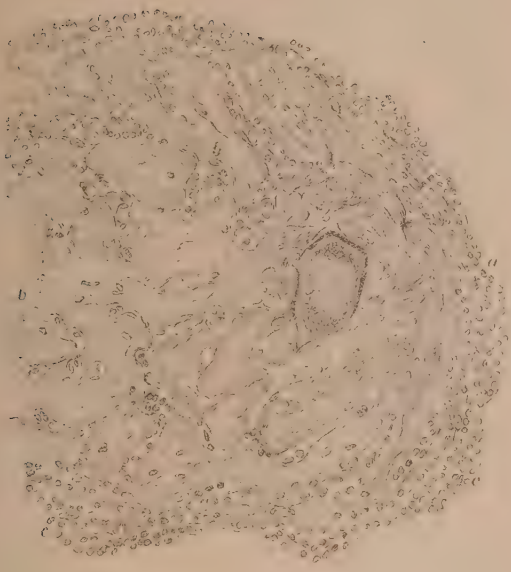


Fig XXX

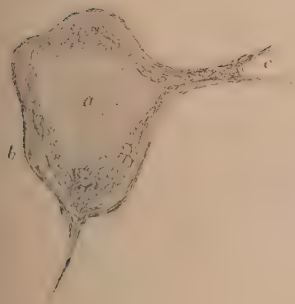


Fig. XXXI.

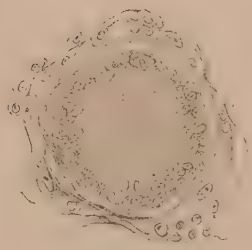


Fig XXVII.

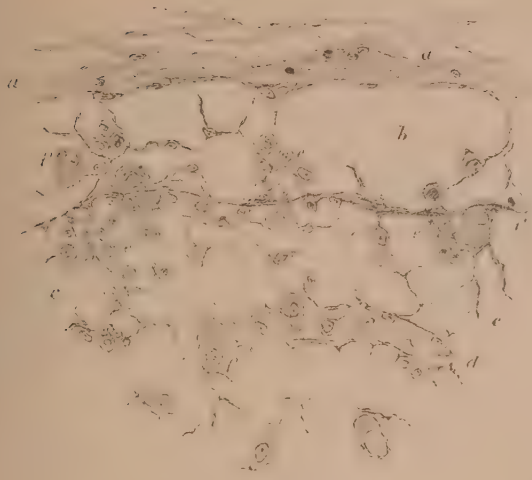


Fig XXVIII

Fig. XXVIV

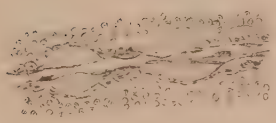


Fig XXVV

Fig XXVVI

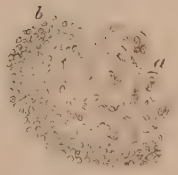


Fig. XXXVII

Fig XXXVIII.

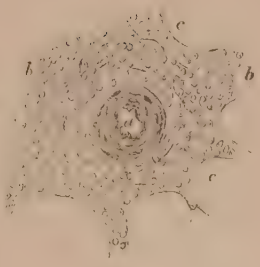


Fig. XXXIX

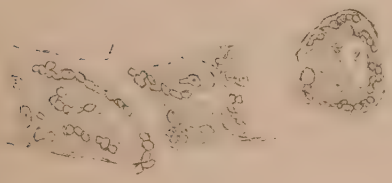
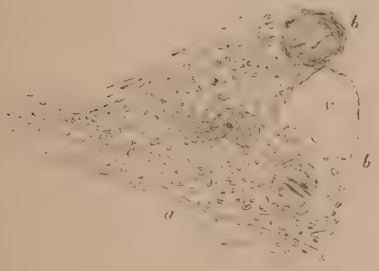


Fig. XL.



No. 4.

Report on the so-called Enteric or Typhoid Fever of the Pig, by Dr. Klein.

I propose to give in this memoir a preliminary account of the results of an inquiry into the disease commonly called Pig-typhoid. Dr. Budd, in a lecture to the Members of the Royal Agricultural Society in 1865, and in his well-known treatise on Typhoid Fever, speaks of this disease in the pig as of the "exact counterpart of typhoid fever in man;" and Professor Wortley Axe, in his recent remarks on typhoid fever in pigs (the "Veterinarian," July 1875, p. 489) concurs with this assertion of Dr. Budd, by trying to show that in etiological, clinical, and anatomical respects both diseases are identical.

Being myself engaged in studying the anatomy of typhoid or enteric fever in man (see No. VI. of this series of Reports, 1875), I was naturally anxious to see whether more light could be thrown on this disease by an experimental and anatomical inquiry into its "counterpart" in the pig. I was therefore greatly disappointed when at the very outset of this inquiry I found that in an anatomical sense the two diseases are essentially different from each other.

It is admitted by all pathologists that the anatomical lesions in human typhoid are of so definite and specific a character that by them, and by them alone, the disease can be recognised in most cases. As I shall show, the anatomical lesions in pig-typhoid are likewise of a very specific nature, being not only very characteristic of this and no other disease in the pig, but also essentially distinct from the human typhoid. It is true the pig-typhoid bears some resemblance to real typhoid in man, but this resemblance is not greater than that amongst infective diseases in general. As is well known, pig-typhoid is a highly infectious disease, associated with an eruption of the skin and ulceration of the large intestine. It has been assumed that the intestinal discharges are the carriers of the contagion, but this assumption seems not to have rested on any direct experimental proof; though from Professor Axe's experiments, it appears that lymph from the pustules of the skin of diseased animals has the power of producing the disease when inoculated into the skin of healthy animals.

I have succeeded in proving, experimentally, that the disease can be produced by inoculating into healthy animals matter obtained from the ulcerations of the intestine; and likewise that the blood of the diseased animals, at a stage when all symptoms are well developed, does not necessarily contain the contagium. In the latter respect the pig-typhoid is essentially different from anthrax, with which it is usually confounded by continental writers on account of a certain similarity of the anatomical appearances in the two diseases; for in anthrax the blood, as is well known, is pre-eminently loaded with the contagium.

A.—The experiments to be recorded in the following have been carried out in conjunction with Mr. W. Duguid, veterinary surgeon at the Brown Institution. They were all performed on young animals.

Experiment 1.—Two perfectly healthy pigs were fed on a piece of large intestine full of ulcers; the material was used perfectly fresh, just as it was removed from the animal that had been killed for the purpose of the research. The animals remained perfectly healthy.

Experiment 2.—Small pieces of the spleen of a typhoid pig, full of whitish nodules of different sizes (*see* the following chapter), were rubbed up with three-quarters per cent. saline solution; of this material one healthy pig received a considerable quantity as food; a few divisions of a Pravaz syringe of the same material were injected into the skin of the groin of another healthy pig. The first animal died on the eighth, the other on the twelfth day; in both cases the "typhoid" symptoms were very well marked.

Experiment 3.—A healthy pig received into the skin of its right groin half a syringe full of the blood and juice of a swollen lymphatic gland, taken from an animal recently dead of the disease, and in which all the anatomical appearances were very well marked. The infected animal showed no signs of the disease for sixteen days, except a small hard nodule (the skin not adherent) in the subcutaneous tissue at the seat of the injection; so that we are quite justified in assuming that the result of the experiment was negative. And this is of very great importance, inasmuch as it tends to furnish direct additional proof of the difference between anthrax and the disease in question; the former being pre-eminently infectious through the blood.

Experiment 4.—From the same pig as in preceding experiment, fresh material was obtained (by scraping) from an ulcer of large intestine, and this material, having been suspended in three-quarters per cent. saline solution, was injected into the skin of the groin of a healthy animal. After ten days, the animal died, with exceedingly well-marked appearances of pig-typhoid in skin, intestine, lung, and lymphatic glands. The inguinal lymphatic glands near the seat of inoculation were especially enlarged, and deep red. The soft palate was swollen and contained follicular ulcerations.

Experiment 5.—Ulcerated parts of intestine of the same animal as that used in experiments 3 and 4 were kept macerating in water for three days, and then swallowed by a healthy animal. This animal died after thirteen days, under very marked symptoms of pig-typhoid: the appearances of skin, intestine, lung, lymphatic glands, &c., being exceedingly well developed, much more than in experiment 4.

The experiment does not, however, prove, as it seems to do, contrary to the experience of experiment 1, that the disease may be communicated by the food; for the very important fact of the infective material having had to be introduced by force must not by any means be lost sight of, as rendering more than possible that in the struggle superficial injuries to the mucous membrane of the mouth may have been the means of effecting inoculation, and that, therefore, this experiment 5 may belong to the same category as experiment 4, *i.e.*, inoculation through direct injection into the connective tissue of the integument. Whether this is so or not we intend to determine by new experiments.

Experiment 6.—The last experiment for the present, but not the least important one, is this: The same animal that had been inoculated with blood and juice of lymphatic glands, and, as we have seen, remained healthy, was again inoculated into the left groin on October 19, but this time not with blood, but with material obtained (by scraping) from an intestinal ulcer of the animal that had died in consequence of experiment 5.

The animal showed very little marked alterations while alive, but, being killed after 12 days, was found to present the following changes: At the seat of the second inoculation there was an abscess in the subcutaneous tissue, this being at the same time closely adherent to the skin. The inguinal glands of the same side much enlarged and very red, so also the lumbar, sternal, and bronchial

lymphatic glands. The two last named had the very characteristic aspect of the lymphatic glands in pig-typhoid : *see* the following chapter. The mucous membrane of the intestine pale, except at the ileo-cœcal valve, which contained a few very small defects of the mucosa ; and microscopic examination proved unmistakably that the mucosa at the ileo-cœcal valve was diseased, only though a mild degree : *see* the last chapter.

The appearance of the lymphatic glands, and the microscopic examination of the intestine (ileo-cœcal valve) in this case, leave no doubt about the animal having been suffering under a very slight degree of pig-typhoid. This experiment contrasts in an important manner with experiment 3 : for both were performed on the same animal ; but in experiment 3, where blood and juice of lymphatic gland had been used as inoculation-material, no disease was produced, whereas in experiment 6, where material of an ulcer had been inoculated, the animal became smitten with pig-typhoid. It might be argued that the condition of the lymphatic glands and intestine as found after the animal was killed may be, perhaps, referred to the first inoculation ; this objection can easily be disposed of, for the microscopic examination proved the changes of the lymphatic glands and intestine to be of recent date ; and besides the characteristic typhoid charges of the inguinal glands near the seat of the second inoculation are quite conclusive.

It is, however, clear to us that in order to arrive at definite conclusions we have to repeat the experiments. As far as they go at present we are inclined to assume—

(1.) That the skin of the diseased animals contains the contagium, as appears from the experiments of Professor Axe.

(2.) That the ulcers of the large intestine, and likewise the diseased spleen, contain the contagium, as appears from my experiments 2, 4, 5, and 6.

(3.) That the contagium is probably not contained in the blood and lymphatic glands at a late stage of the disease, but before this negative conclusion is accepted, additional experiments are particularly requisite.

(4.) That the disease can be produced by inoculation from intestinal ulcers into the skin, as appears from my experiments 4 and 6.

(5.) That whether the same can be achieved by simple feeding with matter of the intestinal ulcers is doubtful, *see* experiments 1 and 5.

Whether the contagium is also contained in the lung, and whether the disease can be produced by inoculating directly into the blood, are questions which cannot be answered without additional experiments.

B. The following are the appearances presented by our animals at the post-mortem examination :—

(*a.*) *Skin.*—In most of the 12 animals that were examined the skin was affected. The skin about the perineum, symphysis, and groins is swollen and of diffuse red colour, so is also the skin of the neck. The ear-lobes much swollen, especially near the tips, and red. The same of the skin of the nose. In two cases there was no distinct rash, and in one case there were in skin of groins, and especially in both ear-lobes, (a few in former, numerous in latter place) smaller or larger necrotic patches of the superficial part of the skin, including epidermis and corium.

(*b.*) *Intestine.*—Small intestine shows, as a rule, hyperæmia, and in some cases ecchymosis in the mucous and submucous tissue, and the serous covering. In some rare cases the same is seen also in the stomach. Large intestine shows always the most characteristic appearances. There are at least smaller or larger, isolated or confluent,

generally roundish, ulcerations at and around ileo-cœcal valve, the rest of the mucous membrane being hyperæmic, even to ecchymosis. In the highest degree the whole large intestine down to the rectum contains ulcers; in the cœcum they are confluent, and measure several inches, extending transversely as well as longitudinally; while the whole remaining mucous membrane of the large intestine is much thickened, and in some parts the submucous tissue contains large accumulations of blood. The ulcers are of various aspects. The following forms may be seen: very minute, well-defined, prominent, yellowish-whitish specks of the size of a millet or hempseed; then somewhat larger, more flattened, prominent, circular or oval yellowish patches (with which in one case the whole mucous membrane of the cœcum seemed quite covered), of the size of a hempseed, up to about $\frac{1}{8}$ of an inch in diameter; next, flat, circular, or slightly oblong patches, situated on the crest of a fold of the mucous membrane, in size from $\frac{1}{8}$ to 1 inch in diameter, generally black or grey (from bile pigment), except a very conspicuous and, I may almost say, characteristic prominent rim which is yellow. The ulcer generally shows a pale, central, or eccentric disc, around which the rest of the ulcer is arranged as concentric rings. Between these flat ulcers with concentric layers and those uniform, yellowish-white, prominent patches and nodules there are all intermediary form; this is easily understood if it is borne in mind that as the latter increase in size the central part is transformed into that black or greyish mass. Besides these there are very often found on the surface of the mucosa minute whitish specks, just perceptible by the unaided eye. In one single instance have I seen ulcerations of the lower part of ileum. This case had exceedingly numerous ulcerations of the large intestine. The two ulcers of the ileum were quite different from the ulcers generally found in the large intestine, for they were oblong, deep pits, surrounded by a thick, prominent wall of swollen mucous membrane, very much the same as ulcers of human typhoid; on the peritoneal surfaces there was an elevation corresponding to them.

The above-described ulceration of the large intestine of the pig cannot in any way be confounded with the characteristic ulcers of human typhoid: the differences are really striking on the most superficial inspection. The only similarity may be said to exist between those early cases of human typhoid which French writers call *la forme bouttoneuse* (where the mucosa of the lower part of ileum and cœcum is studded with small papular structures due to enlargement of solitary lymph-follicles and local accumulations of lymphatic tissue), and the forms of pig-typhoid where the mucosa of the cœcum is covered with slightly elevated papules or patches; but under any circumstance the microscope reveals a marvellous difference in the two diseases, for in the pig-typhoid these patches whether nodules or ulcers, *have absolutely nothing whatever to do with lymphatic follicles*, whereas in human typhoid we find in the first stage round or generally oblong, prominent, papules or patches of swollen lymph-follicles, surrounded by swollen mucous membrane, after which stage the greater part of the swollen lymphatic patches dies and is finally discharged as a slough, leaving behind a pit-like excavation bordered by elevated overhanging mucosa.

Besides the intestine, the following lymphatic glands present very characteristic appearances; the mesenteric glands, especially those of the large intestine; the bronchial glands; the chain of glands along the thoracic (descending) aorta; the sternal glands; and the submaxillary lymphatic glands. The glands are much swollen, slightly firmer than normal or more or less red, in severe cases dark purple or even black and when cut into letting a considerable amount of red fluid ooze out.

At the same time it may be seen that the chief seat of red colourisation is the cortical part of the gland, from which it extends for a greater or smaller distance into the medullary part according to the greater or smaller severity of the change.

In a few cases we observed ulceration also of the organs of the throat. In one case these were symmetrical ulcerations of the mucous membrane of the gums and cheeks, of the front part of the tongue, of the hard and soft palate, and of the epiglottis. The ulcers were of a dark grey colour; and what was most conspicuous about them was their marvellously symmetrical distribution on the two sides of the above organs. In another case we found follicular abscesses in the soft palate; they were very numerous, and the whole organ was much increased in thickness; there was an extensive ulcer in the median line of the epiglottis next the free edge. In a third case we found ulcerations of the gum and cheeks, of the tongue and hard palate; the soft palate contained numerous follicular abscesses; the epiglottis and the mucous membrane at the entrance of the larynx showed hyperæmia and œdema. The epiglottis in addition was possessed with an ulcer. It is noteworthy that these three animals in which we found affections of the throat came all from the same place. In a fourth case, produced by inoculation of matter from intestinal ulcers into the skin, we found follicular abscesses of the soft palate, the organ being much swollen.

The morbid condition of the lymphatic glands is sometimes, to naked-eye inspection, very slight indeed; besides the swelling of the gland there may be only what appears a slight hyperhemic condition; but even here the microscope reveals in all cases a very characteristic state, namely, a bursting of blood vessels in the cortical tissue, and hæmorrhage into the lymphatic follicles and sinuses of that part, amounting in severe cases to total destruction of the adenoid tissue by blood. In severe cases the medullary sinuses, and partly also the medullary lymphatic cylinders become filled with extravasated blood. In so far this condition is similar to what is found in anthrax. Now, this state of the lymphatic glands is, as I said, very characteristic, and, combined with the disease of the intestine, is of paramount importance for the diagnosis.

Further important symptoms, and which have not hitherto received due attention, are affections of the lung and serous membranes. Especially the lung-affection has shown itself to be as constant as any of the preceding, even more constant than that of the skin. The state of the lung is this: the slightest degree consists in a distinct mapping out of the lobes and lobules by œdema of interlobular tissue, the lung-tissue of the corresponding parts being at the same time hyperæmic. Then these parts become hepatised and transformed into a heavy, airless, red, transparent tissue; and subsequently smaller or larger opaque or white specks and patches appear in the red substance, and, as they increase in size, become gradually confluent. On a section it may be seen that this is due to the fact that the bronchial tubes become gradually filled with a white, brittle, cheesy mass, progressing gradually from the finest ramifications on to the larger branches of the affected lobules and lobes. Finally the whole lobule is transformed into a discoloured, dry, hard, friable mass. The pleura of the corresponding parts is of course inflamed, being in some cases exceedingly thick, and covered with false membranes. In severer cases the greater part of one lung and portions of the other may be thus changed, and on the external surface there may exist smaller or greater ulcerations. Except in very light cases there is generally a certain amount of pleural exudation; and in severer cases the pleura contains a considerable quantity of a thick, offensive, yellowish, or discoloured exudation. In some severer cases the pericar-

dium is also inflamed, containing a large quantity of exudation, and its walls being much thickened by false membranes. The same is also the case with the peritoneum, this being in some cases hyperæmic in parts, or even covered with solid lymph and pus. We have had cases where there was no skin eruption, slight intestinal change, and extensive pleuro-pneumonia, pericarditis, and pleuritis.

The next organ of importance is the spleen. The spleen is of dark colour and sometimes enlarged; in some cases it appears not altered in size. In one case it was remarkably enlarged, having throughout it irregular nodular structures, from the size of a pin's head to that of a pea or even larger, whitish in appearance and of firm consistency.

The liver is in severe cases enlarged and very full of blood. The kidney is sometimes also changed: there is hyperæmia of the pyramidal parts, and underneath the capsule, which may be easily stripped off, there are visible on the surface of cortex hæmorrhagic round spots of the size of a pin's head, while similar spots, but scarcer, are met with in the cortex and pyramids. The severer the case the more numerous the hæmorrhagic spots.

Thus we may say that the skin, large intestine, lymphatic glands, and lungs are the organs most commonly affected, and that changes of the serous membranes, the spleen, liver, and kidney, and likewise of the organs of the throat, are of less constant occurrence.

(C.) Microscopic examination.

(1.) *Skin.*—I have examined the microscopic character of those parts of the skin which show the diffuse redness, and in which the skin is being at the same time thicker than in normal parts. The longer the animal lives the more swollen become these parts, as is best shown on the ear-lobes: the pendent parts of these becoming transformed into deep-red, thick, puffy masses, from the surface of which the epidermis peels in greater or smaller flakes. Not seldom are there to be seen smaller or larger roundish or irregular brownish blotches and scabs on the ear-lobes as well as groins and skin of haunch, which blotches and scabs correspond to a necrosis of the corresponding parts of corium. The microscopical characters are these: in the lighter cases as in the earlier stages the corium is œdematous, as is very beautifully shown in the skin of the ear-lobes near the apex by the exceeding distinctness of the lymphatic vessels and the distended interfascicular lymph-spaces which are easily traced to open into the lymphatic vessels. The blood vessels of the corium (including arteries) are more or less distended and filled with blood or plugged with fibrin. Generally the fibrinous plug does not fill up the whole length or breadth of the vessel, nor does it present the ordinary aspect of fibrin in the blood vessels *i.e.*, a felt-work of fibres, but resembles a yellowish cylinder, of so dense a structure that the constituent fibrils are hardly distinguishable; other parts of the vessel contain blood. It is clear from this that there has been existing in the vessels stasis of blood, and that this latter has undergone congulation.

Around the vessels we find lymphoid cells; besides these we find in some cases a very great number of large coarsely-granular cells very deeply staining in hæmatoxylin, with a relatively large, clear, vesicular nucleus; the same cells will be mentioned as occurring in the intestine. The sweat glands are greatly distended, and often filled with blood more or less charged. The connective tissue of the corium contains, in a more advanced stage, in its distended interfascicular lymph-spaces, fibrinous exudations, and in still later cases the tissue becomes more or less flooded with lymph-cells starting from around the vessels and extend-

ing into the interfascicular spaces. And finally the superficial parts of the corium change into a necrotic decolourised mass, the elements of which break down and are transformed into débris. On the ear-lobes, and also in other parts of the skin, I have seen the epidermis becoming very much thickened when the inflammation has reached a high degree.

(2.) *Intestine.*—The mucous membrane of the large intestine shows the following changes. The capillary vessels next the surface very much distended and filled with blood, occasionally ruptured, so that blood is extravasated in the mucosa underneath the epithelium. Genetally the epithelium at the mouth of Lieberkühn's crypts detached and in the act of breaking down. The same is the case with the epithelium covering the mucosa around the mouth of the crypts; at these places the epithelium is raised from the mucosa by the presence of cavities filled with fluid, in which are suspended cells, granular matter, and blood. The epithelium of these parts is quite different from the normal condition, the cells being much shorter, and their nuclei swollen up; this leads to the cells breaking up into small elements; and finally the epithelium is altogether discharged. The mucosa is at the same time much thickened by the presence of lymph-corpuscles. The lymph spaces around Lieberkühn's crypts distended. In the superficial parts of the mucosa, as well as in the submucosa, there are in most parts present large uninuclear cells, which are conspicuous by their coarse granulation, and staining very deeply blue in hæmatoxylin. They are present also in great numbers in the connective tissue of the lymphatic glands, and also occasionally in the skin (see above). In the mucosa of the large intestine, and in the lymphatic glands, they are seen to be of the most different shapes: spherical, oval, spindle-shaped, branched, or irregularly drawn out; and this difference in shape makes it very probable that the cells in question are amœboid. The Lieberkühn's crypts are, as a rule, full with mucous secretion; the cells of the epithelium, especially in the outer portion of the crypts, are goblet-cells filled with mucus. In parts more affected the epithelium of crypts is loosened, and at some places perfectly removed from the glands. In other glands the nuclei of the epithelial cells are enormously enlarged, and the cells changed into spindle-shaped or irregular bodies. In this condition we find the mucous membrane over most parts of the large intestine. In some cases there is copious hæmorrhage in the submucosa, or rather the lymphatic vessels of the submucosa are very much distended and filled with blood, derived, no doubt, from broken vessels. In that blood we find, however, hæmatoidin crystals, and besides a peculiar arrangement of the blood corpuscles; these are arranged around spherical larger or smaller masses, which possess a very uniform and finely granular aspect.

The muscular coat of the intestine is also much swollen, varying to œdematous condition. The fat cells of submucous tissue are mostly filled with a mucous matter.

From the above condition of distension of blood vessels, loosening and partial or total removal of epithelium, we have all intermediary forms to the necrosis and disintegration of the most superficial portions of the mucosa, commencing as very small circumscribed opaque spots in which the tissue is disintegrating, and rapidly increasing in breadth and depth. There is no doubt whatever that the "ulcerations" of the large intestine are merely due to a necrosis of the most superficial part of the mucosa. That part in which the necrosis started remains, as has been mentioned, discernible for a long time as a more or less well-defined speck, around which successive new layers of mucosa have more or less concentrically undergone necrosis.

The submucosa shows at the same time, next the muscularis mucosæ, a reactive inflammation: being full of pus-corpuscles. As the necrosis spreads, the infiltration of the deeper parts with pus-cells increases. Generally the muscularis mucosa seems to be the boundary up to which the necrosis proceeds. In some cases, however, the corresponding part of the submucosa appears likewise involved in the process.

From and even before the first signs of necrosis of the mucosa, viz., when the epithelium begins to break down and be shed from the surface, there are found masses of micrococci, which in some ulcers occupy a great portion of the débris. Also ova of nematode worms I have found in the débris of some of the smaller ulcers.

What we have said hitherto is, I think, quite sufficient to convince anyone that the "ulceration" of the mucosa of large intestine in the pig has absolutely nothing in common with the ulceration of the intestine in typhoid fever of man: the latter being a process entirely limited to the lymphatic follicles of the intestine, which have previously become highly inflamed and hypertrophied.

There are several other points which must be mentioned here, both of great histological interest, and also because of their importance to a right interpretation of the naked-eye appearances of the disease. In some cases when the ulcerations of the intestines are very numerous, the solitary lymph-follicles are seen to be enlarged and peculiarly changed. On the naked-eye inspection we perceive in those cases, in the mucous membrane, translucent spherical nodules, from about the size of a pin's head to hemp seed, or larger, which possess an opaque white centre. Examining them under a microscope we find that in the submucosa there is a larger or smaller saccular cavity, lined by columnar epithelium, and filled with more or less broken-down pus-cells, mucous matter, and granular débris; the wall of the sac containing a few rudiments of Lieberkühn's crypts, is surrounded by adenoid tissue; the cavity of the neck is in communication with the free surface of the intestine by a broad canal occupied by a plug of the same substance as found in the cavity. The plug of the neck and sac generally falls out during preparation. Mr. W. A. Shoolbred, late of St. Bartholomews' Hospital, who examined for me these structures in mucous membrane less changed, found the following: There exist numerous flask-shaped invaginations of the mucosa into the submucous tissue, which flask-shaped cavities are lined by epithelium like the mucosa; the body of the flask situated in the submucosa contains Lieberkühn's crypts like the other parts of the mucosa, with the difference that they are much larger at their blind ends. The flask-shaped invaginations are, as a rule, imbedded in, or surrounded by, a lymph-follicle.

Now it is easy to understand the above condition described as translucent nodules with an opaque centre. One has only to bear in mind: that when the mucosa of the surrounding parts is much inflamed, the cavity and neck of the flask-shaped bodies become filled with pus-cells (gradually breaking down) mucous and granular débris; that under these conditions this cavity becomes more and more distended; and that also the Lieberkühn's follicles in their wall, through stretching, become gradually lost. The tissue of the lymphatic follicle becomes compressed into a narrow zone as the flask-shaped body becomes more distended. Where, however, the flask-shaped bodies do not become plugged up we find this condition: abundant mucous secretion taking place in the Lieberkühn's crypts of the neck, enlargement of the lymphatic follicle around the body of the flask-shaped gland, and penetration of the adenoid tissue into the cavity of the gland, the progressing adenoid issue, however, breaking down when in the cavity of the gland. At

these places the epithelium of the bottom of the Lieberkühn's crypts appears to be changed into a uniformly granular mass with numerous nuclei; the outlines of the individual epithelial cells having disappeared these masses split into several "giant cells," *i.e.*, huge granular masses, with a great number (5, 20, or more) of small vesicular nuclei; whether these giant cells originate from the epithelium of the Lieberkühn's follicles in the manner just described or not, it is certain that at these places the lymph-follicle contains them. But also in other parts of the intestine have I seen "giant cells:" that is to say, where the intestinal mucosa has been moderately thickened, and the surface epithelium at some places has become disintegrated, I have observed in the distended lymph-spaces around Lieberkühn's follicles, huge cylindrical or irregular shaped, finely and uniformly granular masses, at one peripheral place of which were embedded very numerous small elliptical or staff-shaped, or spindle-shaped nuclei, deep stained in hæmatoxylin. The corresponding crypts were much changed, the epithelium being transformed into a thin granular layer in which the nuclei might still be seen, and the cavity of the crypts being distended at some places, and containing masses of lymph-cells, which, however, were in the act of disintegration. Generally at the place where the "giant cell" was found the wall of the crypt was seen to be broken, and in communication with the lymph-space around. Similar giant cells I have found in lymph-spaces in the deeper parts of the mucosa, even extending into the submucosa through the muscularis mucosæ; and finally near the epithelium of the surface where they presented, however, more the round aspect of "giant cells," *i.e.*, their nuclei more like vesicular structures and distributed through the greater part of the centre. I find the giant cells not in all cases, but chiefly in those in which the above-named nodular structures, *i.e.*, swollen flask-shaped glands and enlarged lymph-follicles, are numerous; and generally they are to be found not far from parts containing the flask-shaped glands and lymph-follicles.

With regard to the ulcerations of the mucous membrane of the mouth, gum, hard palate, and tongue, I have to state that here also the ulceration consists in a necrosis of inflamed mucous membrane, in a breaking down of the superficial parts of the mucosa into a coloured débris.

There is one more point which I believe deserves careful attention. In the ulceration of the tongue just mentioned, and at a time when the superficial scab has not become removed, I have seen masses of micrococci situate chiefly in the tissue of the papillæ, but at some places reaching as far deep as the inflammation extends. That they are micrococci was proved by their forming lumps of uniform granules; these lumps stain deep purple-blue in hæmatoxylin, and are thus very conspicuous, and besides resist the action of caustic potash, with which all the rest of the tissue disappears. These heaps of micrococci in locality correspond to the papillæ, and are on the surface of the scab, but underneath the covering epithelium, some parts of this having changed into a dry, hard, discoloured mass, others containing larger or smaller vesicles filled with fluid.

In the soft palate we generally find the lymphatic follicles greatly increased, and the mucous glands much inflamed and infiltrated with pus-cells: the number of these latter increasing, the tissue of the mucous glands becomes destroyed and minute abscesses are formed which discharge their contents through the duct of the mucous gland, which duct has naturally become greatly distended.

(3.) *Lymphatic glands.*—Corresponding to greater or lesser redness of the lymphatic glands we find the cortical parts occupied by greater or

smaller masses of blood, the adenoid tissue becoming at the same time destroyed. But this destruction, of course, depends on the amount of blood present. In the most acute cases we find not only great portions of the cortical follicles transformed into an almost uniform red mass, *i.e.*, swamped with blood, but also some of the medullary cylinders saturated with it. All the lymph-sinuses are in this case also filled with blood, and hence a very striking appearance is produced in some parts: the adenoid cylinders being still intact, while the lymph-sinuses between them and the connective-tissue trabeculæ, are much distended and filled with blood. We may say we have in some parts a very good injection of the lymph-channels with blood. In the cases in which I found (as above mentioned) in the extravasated blood of the sub-mucosa of the intestine the peculiar spherical granular lumps, I met also in the lymph-sinuses of the medulla the same spherical granular lumps. In some mesenteric glands some of the cortical as well as medullary sinuses are filled and distended by fibrin and granular débris, which materials also extend on to the adjacent adenoid tissue. I have seen glands, in which large portions of the adenoid tissue were entirely replaced by fibrin and granular débris..

In the glands from cases of somewhat longer duration, and where there has been extravasation of blood into the cortical adenoid tissue, we find the adenoid tissue in general considerably hypertrophied, and the lymph-sinuses filled with cells of different sizes and aspect. In meselnteric glands of some cases I have found enormous numbers of the giant cells filling up the lymph-sinuses of the medulla. These "giant cells" I can trace down to small granular cells with two or three elliptical clear nuclei, looking very much like epithelial cells. A very striking appearance is produced in some parts, when the lymph-sinuses of the medulla contain giant cells of various sizes closely arranged one at the side of the other: some of the larger ones, containing 20, 30, and more nuclei, seem to break down at their edges into small granular fragments. The connective tissue trabeculæ contain ordinary lymph-cells, and in some cases a great number of the coarsely granular deeply stained wanderers.

(4.) *Organs of Respiration.*—As has been mentioned, the epiglottis showed ulcerations only in a few cases. I have before me preparations through the epiglottis, the submucosa of the posterior surface being in a state of necrosis, and near the edge so broken down as to leave there a deep ulcer, while the mucous membrane of the anterior surface is only slightly inflamed in its submucous tissue: in this I find lymphatic vessels filled with micrococci, *i.e.*, uniformly granular masses stained conspicuously blue by hæmatoxylin, the "granules" becoming more distinct after treatment with caustic potash.

In addition to what has been said of the changes presented by the lungs, I have to mention that the lung is the seat of lobular pneumonia. The walls of the air-cells thickened by round cells and the cavities of the former containing lymph-cells, changed epithelial cells, and in some instances also smaller or larger "giant cells." In the last stages or higher degrees the inflamed tissue becomes transformed into a necrotic disintegrating mass. In the infiltrated, firm, more or less disintegrating parts I find great masses of micrococci filling up capillaries and veins and also contained in lymphatics around arteries. They may be found also in minor bronchi which have become completely blocked up by cheesy inflammatory products, but there the masses of micrococci, conspicuous by their blue colouration in hæmatoxylin preparations, are generally present in greater or smaller lumps between the outer surface of the plug and the wall of the bronchus. In one case I found ova

of Nematode worms in the tissue of the inflamed parts, and in the larger bronchi bundles of the worms themselves.

The pleura is much swollen, and contains great numbers, continuous layers, of lumps of micrococci. The free surface of the membrane is in many parts covered with them. The exudation fluid is also charged with them, as has been mentioned above. The lymphatic vessels of the surface of the lung (the subpleural vessels) are greatly distended and filled with fibrin; also the different trunks situated in the septa of lobes.

With regard to other organs, as particularly the liver, spleen, and kidney, my investigations are yet too incomplete for me to make definite statements; except as regards the liver, that its interlobular connective tissue is greatly altered, by infiltration with lymph-corpuscles, which at some parts form considerable accumulations, amounting almost to nodular new-growths. Similar accumulations of lymph-cells may be observed within the acini of the liver of more advanced cases.

No. 5.

Report on the Infectiveness of Cancerous Tumours, with special reference to Infected Lymphatic Glands, by Dr. Creighton.

The following report will contain a summary account of the work done by me from October 1875 to April 1876, when my investigations came to an end. The report will not present conclusions of the same definiteness as my last report, which gave the results of an investigation that extended over a much longer period. But it will be possible to state broadly the questions that have arisen, and to point out where the observations are defective.

The subject of inquiry was the infectiveness of malignant tumours, as manifested in the secondary formations in the viscera, but chiefly in the secondary transformations of lymphatic glands near to or remote from the primary tumour. The primary tumours were of various kinds, including (1) sarcomatous tumours, growing from bone, periosteum, or other connective-tissue parts, both in the human subject and in the dog; (2) tumours of the stomach, which were in two of the cases more lymphomatous than "cancerous;" (3) one case of cancer of the rectum; (4) tumours of the mamma, both in the human subject and in the dog and cat; and (5) miscellaneous cases, including a remarkable case of what seemed to be primary cancerous disease of the liver in a dog, with infection of portal and mesenteric glands.

The lymphatic glands in one part of the body or another were the commonest seat of infection from the primary tumours, whether these were of connective-tissue or epithelial origin; that circumstance is in accordance with the well-known fact that infection is often found to have reached the lymphatic glands, but to have stopped short of viscera such as the liver and lung. The liver and lung were the seat of secondary tumours in a large proportion of the cases, sometimes the one organ being affected and sometimes the other, and not unfrequently both. Two highly instructive cases occurred, in which both ovaries were secondarily infected, but time did not permit of that valuable material being made the most of. The infected lymphatic glands of which preparations were made, were derived from upwards of twenty different cases. There were, besides, several cases with secondary tumours in the lung or liver, but without any obvious affection of the lymphatic glands.

The one generalisation that stands out conspicuously from the examination of the whole collection of cases, is that the secondary tumours correspond in structure to the primary, even in the most minute particulars. There are, no doubt, some apparent exceptions to the rule; but in the great majority of cases the resemblance is at once apparent, and it is a resemblance of so surprising a degree, that there is no mistaking the significance of it.

The well-established fact of a minute resemblance between the primary tumour and its secondary or infective products affords an invaluable clue to the nature of the infective process as regards tumours. By establishing, at the outset, that resemblance or family likeness between a primary tumour and its secondary products, we are led to conclude that the infectiveness of primary tumours is a property that they develope of themselves, and that no extraneous agency plays any conceivable part therein. In my last report on the physiological processes of the mammary gland, and on its pathological processes as

elated to the physiological, I showed that tumours of the breast were ttributable to certain departures from the physiological regularity of he gland, and that they were, in fact, the consequences of functional isturbance and the expressions of the same. As that is an entirely ovel and apparently *outré* conception of tumours, I think it necessary o say that my former report contained a full statement of details, and hat it represented investigations carried on for a considerable period. Taking, then, the conclusions of that report as a basis, and selecting, or the purpose of illustrating the present subject, a case of mammary umour with secondary tumours or products of infection, the following oints as regards the infection become clear.

The primary tumour is the mammary gland, or a portion of the gland, more or less modified in its structure through aberrations of its unction. The functional disturbances are never exactly the same in my two cases, and the respective modifications of structure, or, in other words, the structures of the respective tumours, are never exactly the same. Although there are necessarily more points of likeness than of unlikeness in two cases of tumours of the same organ, arising at corresponding periods of life, or under corresponding circumstances generally, yet each tumour has its distinct individuality. There are the same differences among individual tumours as there are among individual persons. Now, it is the individuality of the tumour that is reproduced in the secondary tumour. That fact is so remarkable that the attention is at once arrested by it, and it is no less striking as a phenomenon than significant as a point of argument. If the secondary tumour reflects the individuality of the primary, it is obvious that the infective influence emanates from the primary tumour, and that it is a property of the latter developed within it, and seemingly independent of all extraneous influences. Whatever the nature of the infection may be, it appears certain that it is derived in the most intimate way from the primarily diseased part. In other words, the infectiveness of a tumour is a property of the cellular elements of the tumour and of their juices.

The investigation was then directed to find out more particularly the nature of this infective property, and the mode of conveyance of the infection to the neighbouring lymphatic glands and to the viscera. In my first report I arrived at the conclusion that secondary nodules in the liver sprang up throughout the organ, through a process of endogenous cell-formation that took place in the liver cells at particular spots. The new cells, formed more or less obviously out of the liver cells after the endogenous mode, became the secondary tumour cells. The examination of other cases of secondary liver tumours, collected in the interval, confirms this view. The process was especially well marked in cases of lymphomatous tumours. The secondary tumours of the lung are a more difficult subject ; but it may be mentioned that the endogenous process of cell-formation is found to be in progress in an unusually clear way in lung alveoli forming the boundary or the periphery of tumour nodules, the greatly swollen epithelium of the alveoli being the cells in which the endogenous process was taking place. The two cases of secondary ovarian tumours, so far as they have been investigated, appeared to be highly instructive as regards the nature of tumour infection. The ovary appears to be the only part liable to secondary tumour process which impresses a certain character of its own on the secondary growth, or remains other than passive under the working of the infection on its tissue-elements. In each of the two cases of tumour infection, both ovaries were affected and both were *cystic*. One of the cases occurred in Mr. Simon's practice, at St. Thomas's Hospital, in a girl aged 18, who had a sarcomatous tumour growing from periosteum at the

metatarsus, with infection of the inguinal lymphatic glands on the same side, as well as of other lymphatic glands within the abdomen, and with secondary tumours of the lungs. The tumour process could be seen in the stroma of the ovary in various stages, and at some points the exact periosteal overgrowth of the primary tumour was reproduced. The other case occurred in a bitch, that had suffered from mammary tumours for several years. The "sympathetic" connexion between the ovary and mamma may serve to exclude this case from the category of pure infections, and the case is otherwise too difficult to be gone into here without further study of it. It was specially to the infective process in lymphatic glands that attention was directed in the present inquiry; and the rest of the report will be occupied with an account of my somewhat inconclusive examination of infected lymphatic glands, with particular reference to the nature of the infection derived from the primary tumour, and to the form in which it was conveyed.

This subject has not hitherto engaged a great deal of attention, but there have been several important contributions to our knowledge of it within the last twenty years. In particular, Professor Billroth has made investigations of the lymphatic glands in a variety of infective processes, including, among others, those of acute inflammation, scrophulosis, typhoid fever, and cancer.* The infected mesenteric glands in typhoid fever were studied by Virchow, and compared with the lymphatic glands in other infective processes.† The infection of axillary lymphatic glands in a case of cancer of the breast has been described by W. Müller.‡ The general question of lymphatic gland infection has also been treated of by Hansen,§ with special reference to leprosy and scrofula. A more than usually elaborate account of the infection of bronchial glands in a case of cancer of the œsophagus has been published by Gussenbauer.‖ It will not be necessary, in the sequel, to refer to more than the general conclusions of those writers.

Several of the cases in my collection of lymphatic gland infection from tumours appeared to be especially well adapted to show the nature of the infective communication between the seat of primary disease and the lymphatic gland. These were cases of mammary tumours in the bitch, where the lymphatic glands, especially those beneath the inguinal portion of the mamma, were affected with the disease. In the third section of the physiological part of my previous report I described at length the nature of the physiological relation between the secreting gland and its lymphatic glands. The lymphatic gland was a kind of depuratory apparatus, receiving the cellular waste of the secreting gland, and reducing it to the uniform condition of lymphoid cells. The most noticeable and unmistakeable form of waste cells were large nucleated granular cells, containing a yellow or brown pigment. Those cells, being waste products of the imperfect secretion, were conveyed to the neighbouring lymphatic glands in large numbers, and in many preparations they could be seen occupying the lymph sinuses. The pigmentation of the cells enabled them to be traced easily from their origin within the acini to their final disposal and utilisation in the lymphatic gland. Such, then, being the well-marked relation between the secreting gland and its lymphatic appendage in health, the question naturally arises

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* *Beiträge zur Pathologischen Histologie.* Berlin, 1858; and in *Virchow's Archiv*, Vol. 21.

† *Würzburger Verhandl.* I. 86.

‡ *Henle und Pfeufer's Zeitschrift*, 1863.

§ In a memoir published at Christiania, 1871.

‖ *Archiv für Klinische Chirurgie*, 1872.

whether the "infection" of the lymphatic gland from a diseased mamma is in any way dependent on a modification of the health relationship. If that should prove to be so, the infection of the lymphatic gland would be placed on a different footing from the infection of the liver and lung. The last-named viscera are nothing more than a convenient soil for the infective process to plant itself upon, whereas the lymphatic glands near the mamma are not merely dense masses of parenchyma liable to be attacked by the infection, but they are also physiological adjuncts of the primarily diseased organs, and part and parcel of the secretory apparatus. It will therefore be a first subject of inquiry, whether the infection of the mammary lymphatic glands is in any way incidental to the physiological part that they play towards the secreting gland.

One case may be taken as an illustration of the problem here presented. The tumour occurred in a bitch at the inguinal end of the mamma on one side. It consisted mainly of a thickening of a small part of the mamma and of one or two circumscribed small nodules. In removing the affected part of the mamma, it was found that a cluster of lymphatic glands, lying immediately beneath the mamma and embedded in fat, were both enlarged and otherwise changed, and they were removed adhering to the mamma along with some of their surrounding fat. Two of them were about half an inch long and somewhat less in their shorter axis. On cutting them open there were differences at once apparent in different parts of their substance, certain tracts being deeply pigmented and denser, while other parts were free from pigment and more elastic. The microscopic examination showed in various places a definite new formation. The new structure generally existed within the limits of a follicle. There were two varieties of it. One of them was a structure composed of large rounded spaces lined with a kind of cubical epithelium with large nuclei. This structure closely resembled the appearances in certain parts of the primary new growth. The new structure in another of the lymphatic glands was different. It consisted of long columns of epithelial-like cells extending into the central clear space of the follicles with their extremities free, or forming a network of trabeculæ crossing the area of the follicle. That kind of structure is quite definite and is often found in mammary tumours of the bitch; in this case the primary tumour or the diseased portion of mamma did not show precisely those appearances at any part of it that was examined, but it showed a papilliary kind of structure that had doubtless grown out of an earlier form such as that found in the lymphatic gland.

Leaving as it stands the question of resemblance between the primary structure and that in the lymphatic glands, we shall turn to consider how the new structure in the lymphatic glands was acquired.

The glands, it has been said, were obviously pigmented more at some parts than at others. In the normal condition the same lymphatic glands are often found to have their lymph sinuses occupied by round granular pigmented cells, and the follicles are sometimes found to be strewn with the grains of free pigment. In this pathological case, the most noticeable point of difference is that the large round pigmented cells have overflowed from the lymph sinus into the substance of the follicle. But there are certain other changes in the diseased gland which may or may not be antecedent to, or the cause of the overflow of mammary cells from the lymph sinuses into the follicles. The lymph sinuses themselves are often seen to be more obstructed by their contents than normally. The fibres stretching across them and forming their filtering or depuratory apparatus are broader and thicker, and the pigmented cells that ordinarily pass through them, and become stripped

of their pigment and cell substance in so doing, appear to have taken up as if permanent positions; the lymph passage is in fact clogged up. There is, however, a more general change in the parenchyma of the gland, of which the change in the lymph sinuses is perhaps only a part. Throughout the whole of the gland the lymphoid cells have become swollen. In ordinary circumstances and under ordinary methods of preparation, the lymphoid cells appear as naked nuclei. In the beginning of the infective cancerous process they are all found to have a distinct investment of protoplasm; the nucleus is now surrounded by a margin of cell substance, and the closely-packed cells of the follicles have often a rectangular or polyhedric shape, resembling epithelium. The swelling of the parenchyma is quite general throughout the gland, and it is difficult to say, by what agency issuing from the seat of primary disease, it has been brought about. The swelling of the parenchyma of the secondarily infected organ appears to be the first step in the process of cancerous infection, and the cause of it remains obscure; so that at the outset of the inquiry we have to leave an important point unexplained.

The swelling of the lymphatic parenchyma is not peculiar to the infective process of malignant tumours. It occurs, generally speaking, in every infective process, including acute and subacute inflammation, scrophula, tuberculosis, syphilis, typhoid fever, &c. The resemblance in their initial stage between certain of those processes was made out by Virchow, and between others by Billroth; so that it may be said to amount to a generalisation. In the cases of infected mammary lymphatic glands, it is difficult to decide whether the swelling of the lymphoid cells of the parenchyma preceded or followed the overflow of cells from the diseased part into the follicle, and it remains therefore doubtful whether those cells, by their contact or otherwise, were the agents of infection. But whatever the cells brought from the diseased mamma may have had to do with the initial swelling of the parenchyma, which is common to this particular infective process and to every other infective process, there is little doubt that those cells sometimes determine the permanent structural changes in the cancerously-affected lymphatic gland.

To return to the case of lymphatic gland beneath the diseased mamma of the bitch. The new growth in the lymphatic gland consisted, in some places, of papilliform processes or trabeculæ of epithelial-like cells, resembling a structure of common occurrence in primary mammary tumours. In the primary disease that structure is dependent on outgrowths of the epithelium lining the acini; several varieties of this primary process in the mamma were described and figured in my last report. In the secondarily affected lymphatic gland, the same papilliform processes and trabeculæ occur, and they appear to arise from the wall of acinus-like cavities, just as they did in the acinous gland. How then does the lymphatic gland assume this wonderful imitation of the pathological process in the secreting gland?

In the first place it is the dense parenchyma of the follicles and cylinders that is the seat of the changes; the lymph sinuses may be disregarded for the present. The lymphoid cells of the follicles, it has already been pointed out, have acquired an investment of protaplasm or a fringe of cell-substance round the nucleus. As in the first stage of all the infective processes, the lymphoid cells have acquired something of an epithelial character. In the other infective processes, the swelling of the parenchyma is only a passing phase; the swollen cells undergo rapid changes either in the way of suppuration or necrosis, and the process, if it runs its course, ends in cicatrization. The tumour process is eventually distinguished from all of these; although in some

of the cases of tumours to be afterwards mentioned, there is a resemblance with other infective process beyond the point of parenchymatous swelling. In the particular case, however, that has been selected for the general description, the lymphoid cells permanently retain their protoplasmic investment and become endowed from that time forward with the persistent vitality and power of increase which distinguishes tumour cells.

Up to this point we have found that the cells of the whole follicle become uniformly changed into epithelial-like cells. It is out of that matrix-tissue that a particular structure is carved, according to the pattern of the primary tumour. The compact follicle becomes changed into an acinus-like cavity, with papillary processes rising from its margin (or its floor), and projecting free into its space, or with trabecular bands crossing it in certain regular directions. The carving out of the tumour pattern from the compact cells of the follicle is effected by means of the large granular pigmented cells. These, it has been mentioned, overflow from the lymph sinuses into the follicles. They are frequently seen lying among the cells of the follicles, and in favourable specimens, their agency in transforming the follicle into a portion of new growth after the primary pattern, can be inferred in a general way. Many of them become distended, a cavity forming in their substance; they are thus transformed into large vesicles, which press the follicular cells in certain directions. The vesicles then break down, and the follicular cells remain as epithelial-like processes or trabeculæ, with spaces between them, and looking as if they had grown up from the rows of cells lining the wall of a cavity. In the primary tumour the round spaces, with numerous knob-like or papillary projections, are actual acini of the gland, the lining epithelium of which has taken on the common form of papillary overgrowth. Exactly the same appearance is produced as a secondary result in the adjacent lymphatic gland; and the striking resemblance, or rather the exact copy, is effected by carving the pattern out of the compact mass of cells of the follicle. The carving-out process is accomplished by means of a particular class of cells, which are themselves destroyed in the process. Now the large pigmented cells, through whose agency the pattern of the primary tumour is imprinted on the secondarily-affected lymphatic gland, are derived from the primary tumour, or, in other words, are products of the primarily-diseased gland.

That is, however, only one of the ways in which the lymphatic gland is transformed into the likeness of the primary tumour. Another mode, which is an interesting modification of the first, is as follows. It has been observed especially well in the affected lymphatic glands of a case of mammary tumour of the human subject. The primary tumour in this case is figured on page 185 and again on page 186 of my last report. It is essentially of the same trabecular structure as the mammary tumour of the bitch just described; the enlarged acini are traversed by anastomosing columns of cells. The structure of the axillary lymphatic gland is of exactly the same kind; there is observed in the primary tumour at certain places a quantity of free brown pigment granules, and collections of red blood corpuscles, and even in those small and, as it were, accidental circumstances, the lymphatic gland resembles the growth in the mamma. The development of the new growth can be traced through various stages. The first stage is that of general swelling of the parenchyma, depending not so much in this case on a distinct fringe of protoplasm round the previously naked nuclear lymphoid cell as upon a uniform enlargement of the lymphoid cell in its nuclear state, the cell becoming at the same time more granular. The next stage resembles

that found in the other infective processes. The swollen parenchyma appears to undergo a general atrophy or necrosis. The swollen cells assume an opaque appearance, and fail to colour with the logwood staining fluid. In the other infective processes that stage goes on to the general breaking down of the parenchyma, but in the tumour process the sequel is different. Along certain regular lines throughout the follicle the opaque and, as it were, necrotic cells show a small and brightly-coloured nucleus in their centre. These nuclei are in many cases quite minute points, and such is no doubt their first appearance as young cells in the substance of the old follicular cells. They appear, as has been said, along certain regular lines; and growing up from the old cells along the lines that are as if laid down or marked out for them, they result in a new growth of a definite pattern, the pattern being the structure of the primary tumour. There is in this case, as in the former case, a carving out of the new growth from the compact cells of the swollen follicle, but the carving out is here effected by a residual process. The old cells of the follicle decay except along the lines of the new pattern; and along those lines young cells spring from the substance of the old follicular cells, and in course of time grow up into the form and arrangement of the cells in the primary structure.

A third variety of the mode of transformation of the lymphatic gland substance is found in the epigastric glands in a case of cancer of the stomach. In the primary tumour the epithelial-like cells were collected in alveolar groups between the mucosa and the serosa. The cells lay in the alveolar spaces, packed together without any very definite arrangement. The appearance of the primary structure is simulated in the lymphatic gland in the following way. There is first of all the swelling of the parenchyma; the swollen lymphoid cells then become opaque; and ultimately there arise from them, not along particular lines, but over continuous areas, small young cells, which form the alveolar groups corresponding to those of the primary tumour. But the special interest of this case is in showing the exact mode of origin of the young cells from the opaque and decaying cells of the follicles. The mode of origin is here clearly seen to be that of endogenous cell formation. The young cell lies in a cavity of the parent cell; the smallest of them are minute points like a small nucleus, but even at that stage they seem to lie free in a cavity or vacuole. All the lymphoid cells of the follicle appear to undergo this transformation, and the pale outlines of the old cells can always be seen lying among the endogenous brood even when the latter have reached a considerable size and become independent. I have already described this variety of endogenous cell formation in my first report, treating of the development of secondary tumours in the liver. In the present case of cancer of the stomach there were affected lymphatic glands of various sizes. It is in the smaller glands that the histogenesis of the new growth can be traced, in a large pigmented gland, the size of a pigeon's egg, the tumour structure is perfect and finished, and the cells have everywhere their epithelial form and arrangement.

The three cases hitherto mentioned are cases where the semblance of the primary tumour was produced in the lymphatic gland by a process of adaptation or carving out of the lymphoid parenchyma. I shall add a fourth case to illustrate the extreme form of this mode of infection. It is a case of a sarcomatous tumour, in the dog, the size of a child's head and growing from the ventral surface of the scapula. The brachial plexus of nerves was carried inwards by it, and spread out over its axillary surface, where the nerves, widely separated from each other appeared to bind it down like the cording of a bale. The axillary

lymphatic glands were embedded in the substance of the tumour at its axillary periphery. They could be shelled out from the tumour proper, and were also distinguishable by their colour and density. There were at least half a dozen of these embedded lymphatic glands, and they were upwards of half an inch in their longest axis. On examining them, they were found to be uniformly affected, and to be changed throughout into the likeness of the sarcoma which had enclosed them. In some the process of transformation could be traced; in others the process was complete, the individual cells having lost everywhere their lymphoid character, and assumed the size and form of the tumour cells. So far as the preparations went, the process seemed to have befallen the lymphatic glands uniformly throughout their substance. The lymphatic glands were, for the infective process, nothing else than compact cellular masses presenting at all points an equally favourable soil for the infection. The case may be taken as an example of those in which the physiological arrangements of the gland, the relation of the lymph sinuses to the follicles and the like, go for nothing. The lymphatic gland falls a prey to the infective process as if it had been a crude mass of cells, and as if its complex structure and its perfect mechanism were non-existent.

In such cases it appears hopeless to trace the path of the infection, or to inquire whether it came to the lymphatic gland in the form of a fluid, or in the form of cells, or, as some have supposed, in the form of a contagion of organisms foreign to the body. But if the mode of infection in the last of the four cases, and in other cases, chiefly sarcomatous, that might have been given, seems to baffle all analysis and to be referable only to an inscrutable agency, it borders on modes of infection in other glands that are less and less mysterious. The four cases given as examples all show that the infection acted upon the predominant cells of the gland, or upon the lymphatic parenchyma; and in the first of the cases, the co-operation in the infective process of cells derived from the primarily diseased part, or the primary tumour, was undoubted. It is this co-operating or determining agency that has to be further inquired into.

In the first of the four cases, the cells derived from the primarily diseased part were large granular pigmented cells. Those cells are normal products of the mammary secretion at its periodically enfeebled periods, and in the tumour processes of the bitch, they are produced in unusual quantity and at unusual times. They often contribute largely to the bulk of tumours, being collected in large heaps outside the secreting acini, and when they are stripped of their pigmented cell-substance their nuclei subdivide and multiply in the usual way,

In the healthy condition of the mammary function, they are conveyed to the neighbouring lymphatic glands, in whose lymph-sinuses they are reduced to a nuclear or lymphoid condition, and are so utilised as lymph corpuscles.* Now, in the pathological states of the mammary function, as they may be studied in the bitch, the lymphatic glands may continue to perform this task for the waste products of the secreting gland for a considerable time after the pathological process in the mamma is firmly rooted. In the present collection of mammary tumour cases are several in which the lymphatic glands of the mamma, both at the inguinal and axillary ends of the gland, show the normal relations of all their parts; the follicles containing the ordinary lymphoid cells, and the sinuses being filled with the round yellow mammary cells. But

* *See* Section III. of the first part (physiological) of my last report.

it appears that a time comes when the depuratory apparatus of the lymphatic gland breaks down.

There is, first, stagnation of the large granular cells in the lymph-sinuses, and that is followed by an overflow of them into the substance of the follicles. This overflow may be observed in many cases, and there is no doubt of its close connexion with the process of infection. Side by side with the overflow, there is observed a change in the constant elements of the lymphatic gland. That change is the parenchymatous swelling before mentioned, and it is difficult to say whether the parenchymatous swelling of the constant elements of the gland is the cause or the effect of the overflow of waste cells that are in process of passing through it. The swelling affects not only the lymphoid cells of the follicular tissue, but much more the "fibres" of the lymph sinus. Those fibres are protoplasmic bands, and the nuclei that they appear to contain are merely the circulating cells of the lymph sinus in more or less close apposition to them. At the same time that the lymphoid cells of the follicular tissue become individually larger or more invested with cell-substance, the "fibres" swell up into broad bands, diminishing the meshes between them. The lymph sinus thus appears as if it were clogged, and the depuratory process by which the waste cells are reduced to a nuclear state appears as if arrested. It is then that the waste cells from the mamma overflow into the follicles. The real difference between this pathological process and the normal process is that in the latter the waste cells of the secretion are received into the follicle only after they have undergone the depuratory and reducing process of the lymph sinuses, while in the pathological case they enter the parenchyma of the gland in the form of waste cells and with all the properties of waste cells clinging to them, whatever those properties may be. Having reached the follicles in the condition in which they left the mamma, they there play a distinct part in producing the semblance of the primary tumour in the lymphatic gland.

In the first case mentioned the foreign cells determined the pattern of the new growth, or aided in the carving-out of that pattern, while they themselves did not go to make up its bulk. But there is reason to think, from a number of other cases, that the waste cells from the primarily affected part may themselves contribute by their own substance to the production of the pathological structure in the lymphatic gland.

The two modes of infection have been discussed by previous writers, and have been broadly contrasted, and treated as supporting rival theories. Either the lymphatic gland is transformed throughout its whole substance into the likeness of the primary tumour, or certain fragments from the primary tumour are carried into the lympatic gland where they find a lodgment and grow up into a tumour mass, gradually encroaching upon and causing the atrophy or disappearance of the lymphatic tissue proper. The four cases already given as example, are all illustrative of the first theory; but other cases might be given that would appear to support the second.

The same apparent discrepancy or want of agreement occurs throughout the entire literature of this subject, and not only as between different observers, but as between the different observations of the same observer. Thus Professor Billroth in his earliest papers on this subject wrote:—"Regarding the extension of cancers by the lymph-stream, I "cannot entirely share the opinion of those who here assume a direct "transport of cancer-cells, which are merely conveyed to another place, "there to fulfil their destiny. This view is to me somewhat incompre-"hensible, I might almost say it is conceived too much in the sense of "plant-life. In the widest estimate that I can form of the vital

"powers of cells. I cannot imagine that they swim in the lymph-"stream, like fish in the water, or that, like wandering pores, they "require only to fix themselves in order to grow up into new indi-"viduals. It is much more conceivable that the serum (intercellular "substance), conveyed from the cancer has a certain infectiveness for "other cells, and that thereby a new diseased process arises in a "neighbouring part."* Three years later, Professor Billroth returned to the subject, the lymph-stream within the lymphatic gland having been demonstrated in the interval by His and Frey; and in a case of pigmented cancer of the breast, Professor Billroth did find melanotic cells in the lymph-sinuses of the axillary lymphatic glands, and was disposed to conclude that these were the starting point of the secondary new growth. He especially remarks upon the value of pigmented cells in tracking the infective process. "By making out," he says, "that "the cancer-formation in the lymphatic glands follows the lymph sinus, "that is to say, the normal lymph stream, we are again brought face "to face with the notion of a transporting of cancer cells. It appears "so extremely plausible, from this discovery, to think that the cells from "the cancer reach the lymphatic glands by the lymphatic vessels, and "that they there fix themselves and establish a new centre (*Heerd*). "But proof is wanting that cells of this kind can be transported, or "that they are actually found in the afferent lymphatic vessels of the "gland."†

In the present collection of cases are several in which the new growth begins in the lymph-sinuses. Thus in a lymphatic gland beneath a mammary tumour in the cat, the new structure is found at only a few points in the cortical lymph-sinuses; at those points the fibres of the reticulum appeared to constitute the framework of the new growth. In a lumbar lymphatic gland infected from cancer of the rectum, many cells, that can be traced into their ultimate form of tumour cells, lie in the lymph-sinuses, and where collections of them occur in the follicular tissue, those collections are always definitely circumscribed. Again, in the case of lymphatic glands infected from one of the cases of cancer of the stomach, there can be seen in different preparations, various degrees of encroachment of the tumour cells from the lymph sinuses upon the follicles. But many of the lymphoid cells of the follicles retain their lymphoid character to the last, and narrow tracts of them can here and there be seen extending through a gland that is otherwise completely changed into the likeness of the new growth.

In a large collection of infected lymphatic glands from various kinds of tumours, there is no doubt a considerable want of uniformity in the process of infection. But it may well be doubted whether the appearances can be placed in two distinct categories, or be taken to establish two distinct processes. There is certainly no reason to think that one or other of the sets of observations is wrong, and that the discrepancy arises from defective observation. The discrepancies between the accounts of different observers and between the different accounts of the same observer, depend, without doubt, upon differences in nature really existing. The inference from them, at the utmost, would be that there is more than one mode of infection. But a closer examination seems to show that the process of infection in lymphatic glands is in all cases one and the same. The differences depend upon differences in the degree of intensity of the infection. Those differences in intensity are often exemplified in the same case. It is not uncommon to meet with several

* *Beiträge zur pathologishen Histologie*, p. 201–202.

† *Virch. Arch.*, Vol. 21. p. 441–42.

lymphatic glands affected, and these of various sizes, say from the size of a pea to that of a pigeon's egg. It is true that the smaller glands contain more traces of the normal structure than the large, and from that circumstance it might appear as if the larger glands, as found, had been the first attacked, and that in them the new growth had spread farthest. But the most usual difference between the larger and smaller glands appears to be that the larger had from the beginning undergone a more extensive or a more general initial swelling of their parenchyma, whereas the smaller are only affected at limited spots. And those differences may be said to depend on the initial intensity of the infection.

It is by keeping in view this circumstance that the apparently irreconcileable varieties of the infective proces can be shown to be one and the same. There is not one class of cases in which there is a general transformation of the lymphatic tissue into tumour tissue, and another class of cases in which the tumour tissue of the lymphatic gland is derived from the multiplication of primary tumour cells conveyed thither. But there are extreme cases in which the whole parenchyma of the gland appears to be infected at once by some infective agency which cannot be traced; there are less extreme cases where the whole follicular tissue is transformed by means of cells overflowing into the parenchyma from the lymph-sinuses; and there are cases of feebler infection where the lymph-sinuses are the starting point, and where the transformation proceeds from them throughout the follicle as if in successive zones or from successive centres. The last-mentioned cases are those in which the new growth has seemed to depend on a multiplication of the transported primary cells, and a gradual encroachment upon and supplanting of the normal lymphatic tissue by them. There is no doubt an encroachment; but it is not a supplanting and displacing encroachment, but a transforming encroachment.

It will now be necessary to give some of the detailed observations on which the above conclusion is based. In the first of the group of four cases, it was stated that the new growth was carved out of the swollen parenchyma or folicular tissue by the agency of large granular pigmented cells that had overflowed from the lymph sinuses. More particularly, it was by the vacuolation of those foreign cells that the lymphatic parenchyma was adapted, or transformed into the pattern of the new growth. It is to be observed here that there was no vacuolation of the individual cells of the lymphatic parenchyma. The vacuolation or endogenous cell-formation process has been shown in my first report to be the mode of transformation of the liver parenchyma in secondary tumours, and the same vacuolation of the individual cells of the lymphatic parenchyma is now to be described for certain of the lymphatic glands. In the first case, there was a process of vacuolation, but it took place in the foreign or transported cells; and as the proper cells of the parenchyma were not transformed by that process, those foreign cells overflowing into the parenchyma* may be held to have undergone the vacuolation process *vicariously* for the cells of the part.

The vacuolation process, as an element of the process of tumour infection, can be nowhere seen more perfectly or more unambiguously than in certain cases of infected lymphatic glands. Vacuolated cells are found in lymph sinuses, while the follicles are still in their lymphoid condition. Again, the large protoplasmic cells in which the vacuolation

* This expression is purely figurative, and is used here in the absence of a more scientific explanation of the process, such as a more prolonged study of it will doubtless bring to light.

process takes place are found to have overflowed into the follicles. Sometimes the vacuolating cells form an outer zone to the follicle, at other times they form definite groups in the follicular substance. The products of the vacuolation are the tumour elements. In some cases a numerous brood of young cells is found within the cavity of the parent cell. In lymphatic glands affected in cases of cancer of the stomach and cancer of the rectum, the multiplication of nuclei within the cavity of the parent cell can be observed. It is obviously the same process as that described as follows by Virchow for scrophulous glands:* "In the lymphatic glands the first stage of the process is a very remarkable hypertrophy of the elements by endogenous formation of nuclei. While the cells increase in size five or six times, one sees that the nuclei multiply in pairs, probably by a division pairwise, so that as many as twelve pairs of various size may be counted in the same cell." It may be mentioned that the largest number of endogenous nuclei in single cells occurred, in the present series of preparations, in a case of secondary tumour in the lung of the cat, after cancer of the breast. The cells lay within the lung alveoli, and appeared to be the swollen cells of the alveolar epithelium. A large endogenous brood is however the exception. The most common case is where the vacuolated cell carries an oblong or crescentic nucleus-like body on one side. It is this body, becoming disengaged, that forms the tumour element. Now, the vacuolation or endogenous process is sufficiently characteristic to be traced. It is first seen in large protoplasmic cells lying in the lymph sinuses; it is then seen in groups of the same cells at scattered points in the midst of a follicle; and lastly it is seen all over the follicle. In the last-mentioned stage it is quite obvious that the cells generally undergoing the vacuolation process are none other than the enlarged lymphoid cells themselves. The lymphoid cells swell up, become granular and vacuolate, and thus the transformation into tumour cells becomes general.

An interesting question now arises, Do all the cells that are seen in the infected lymphatic gland undergoing the vacuolation process, belong to the pre-existing elements of the gland, or are some of them conveyed to the gland from without? Again, if there are foreign cells among them, how are they distinguishable from, and what is their relation to, those cells of the part that undergo the same process? It is here that it seems possible to reconcile the discrepancies in the different accounts of lymphatic gland infection.

As regards the lymphatic glands infected from mammary tumours in the bitch, it is possible to speak definitively on the point now at issue, for the large round cells filled with yellow or brown pigment have been shown by me in my last report to be normal waste products of the mammary secretion. In health those waste products are conveyed to the lymphatic gland and are there disposed of; in disease they are conveyed to the lymphatic gland and play a conspicuous part in the infective process. Their agency in carving out the pattern of the primary tumour from the swollen substance of the lymphatic gland has been already described. Leaving the mammary cases for a time, let us consider cases of the stomach and intestine as illustrating a variety of the process. In the affected lymphatic glands in cases of cancer of the stomach and cancer of the rectum there are found cells exactly analogous to the large yellow cells in the mammary cases in the bitch. Those cells are not tumour cells, any more than the large yellow cells are tumour cells. They are large rounded cells, with the peculiar protoplasm of the secreting

* *Würzburger Verhandlungen*, Vol. I., 85.

App. No. 5.

On Infectiveness of Cancerous Tumours, by Dr. Creighton.

epithelium of the stomach. They are the waste products of the secretion of the stomach, in the same way that the large yellow cells are waste products of the mammary epithelium. It is of such epithelial waste cells, or waste products of the secretion, that epithelial tumours are composed; and the cells that are conveyed to the lymphatic gland are not tumour cells, but cells of the primarily diseased part, which, if they had remained in their habitat, would have become tumour cells. They would have become elements of the primary tumour after undergoing a more or less obvious transformation, and they become elements of the secondary tumour by fulfilling the same destiny in their new abode. So far, there is no infection, but a mere change of locality. But their presence in the lymphatic gland leads to a transformation of the cells among which they lie. Whenever they overflow into the follicles, the cells of the follicle begin to undergo the tumour transformation. Now, there are two very instructive varieties in this process which have been adverted to already. In the one, the foreign cells overflow, and are the agents of carving out or determining the exact copy of the primary tumour. This they do by becoming vacuolated and leaving a space in their room, the cells of the lymphatic gland undergoing all the while a direct or non-vacuolar transformation. The foreign cells contribute nothing to the new growth, except its form. The other variety is in striking contrast to this. The foreign cells overflow into the follicles, and there, as well as in the lymph-sinuses, they undergo that endogenous process by which they become the elements of the new growth. They induce the same endogenous process in the lymphoid cells near them, and both contribute *pari passu* to the building up of the substance of the new growth. In this case there is direct vacuolation of every single cell; but in the other case the vacuolation takes place only in the foreign cells, and it may be said to be done by them *vicariously* for the cells of the part. In the one case, also, the initial parenchymatous swelling of the lymphatic follicle took place all over the gland at once; but in those cases where the individual vacuolation of the follicular cells is observed, the parenchymatous swelling appears to break out in limited zones or islands of the gland, and to be in fact the immediate precursor of the vacuolation process in each cell.

The simplest mode of infection may therefore be said to be that in which a considerable number of cells are conveyed from the primarily diseased part to the lymphatic gland, where they themselves undergo a transformation to tumour cells, and at the same time induce, by contact or by some other unknown influence, a similar transformation in the proper cells of the part. The case of gonorrhœal pus conveyed to the conjunctiva and setting up a purulent formation there, is rougly analogous. The analogy cannot be pushed far, as the conditions of an expanse of mucous membrane are different from those of a parenchymatous organ. The analogy, however, holds good to this extent, that as gonorrhœal pus produces gonorrhœal pus, so tumour cells produce tumour cells. Gonorrhœal inflammation is morphologically a simple process, while a tumour process implies the formation of a more or less complex organoid growth.

The mode of infection that comes next in complexity and in obscurity is where a few cells overflow into the lymphatic parenchyma, and determine the transformation of all the cells of the part within a certain radius. There are two instructive points of difference between this case and the last. The few cells that are the agents of infection do not appear to contribute to the substance of the secondary formation, and the cells of the part which alone form the new growth, do not, in some cases at least, undergo the characteristic endogenous transfor-

mation. But the few infecting cells undergo this transformation, and they may be said to do so vicariously for the cells of the part. Through the efficacy of the imported cells, the lymphoid cells of the lymphatic gland assume more or less directly the structure of the primary tumour. Now, it is this direct transformation of the secondary parenchyma into the likeness of the primary tumour that is characteristic of some of the most malignant or intense tumour infections, and it may be said to distinguish sarcomatous tumours as a class, where those tumours do have the lymphatic glands affected. In such cases it is difficult to trace any transport of infecting cells. The whole parenchyma appears to transform itself directly into the likeness of the parent tumour, as if through some unseen and inscrutable agency. But that agency need not be assumed to differ in kind from the so-called vicarious agency of certain cells in other cases. If a few cells originating in, and physiologically belonging to, the primarily diseased part, can determine the transformation of a lymphatic gland by being conveyed to it, but without contributing by their own substance to its new structure, then it is conceivable that a similar influence may operate on the lymphatic parenchyma from a still greater distance, that is to say, from the original habitat of the cells in the primarily diseased part. Certain it is that in tumour-infection we are warranted in assuming no other agency than is contained among the properties of the cell, however obscure those properties may be. The occult influence of the spermatic cells is a mystery large enough to cover all the varieties of infective influence residing in cells, and to make them seem intelligible by comparison. But the problem of tumour-infection presents more points of attack than does the mystery of generation. The spermatic influence is, in its effect, one and indivisible, while the infective influence of parent tumours may vary infinitely in degree. It is from such of those variations as have come under notice in the present research that a certain amount of explanation appears to have been reached. In the simplest form, glandular cells of the mamma or the stomach which would have in time contributed to the primary new growth are conveyed, by the physiological channel, to the lymphatic gland; in their changed situation they not only fulfil their destiny and become tumour cells, but they induce a like transformation in lymphoid cells that they come in contact with. In the next degree, the conveyed cells exert a wider and more direct influence on the lymphatic parenchyma; by their agency the pattern of the primary tumour is carved out of the lymphatic gland. In the least intelligible class of cases, the influence is still more widely diffused and more direct, and is indeed invisible except in its effects. But it is as clearly derived from the primary tumour as in the former cases; for the lymphatic gland puts on the likeness of the primary tumour even to the most minute particulars. In this extreme form of infection, no transport of entire cells can be traced; but we do not therefore seek for an explanation of the infection outside the properties of the cell. Virchow, in treating of purulent infection, was led to think that the infectiveness was inherent not in the forms of cells but in the fluids that are present in or about the cells, and Billroth, in speaking of cancerous infection in the passage already quoted, thought that the infectiveness might reside in the "serum or intercellular substance."

One point remains to be noticed. In the growth of a secondary tumour, whether in a lymphatic gland or in an organ like the liver, there is not merely a resemblance between the individual tumour cells of the secondary nodule and those of the primary tumour, but there is the most remarkable resemblance in the arrangement of the stroma and in the general conformation of the growth. The infection implies not

only a transformation of the cells of an infected area into the likeness of cells of the primary tumour, but it implies also a consensus or co-operation among the elements of the infected part to assume the grouping and general plan of the primary tumour. Nothing can be more striking than to find that a lymphatic gland infected from a sarcoma growing from periosteum, acquires the appearance as if its own sarcomatous cells had grown interstitially within, or from the germinal surface of a periosteal tissue. Yet the mimicry of the infective process is as complete as that. The primary tumour, if it is in an epithelial organ, can be accounted for rationally by following out the functional aberrations of the organ or part, and if it grows from a tissue like periosteum, it can be rationally explained as a departure from the cellular laws of nutrition or of growth. The ultimate form of the primary tumour, one may say, is very much a matter of chance; its design is not predetermined, but it is developed step by step, and it may vary according to circumstances. But in the secondary growth there is present from the beginning of the process a fully prepared design, which is followed as if implicitly. The primary tumour is the result of natural laws and their aberrations; but the secondary tumour is the result as if of a single creative fiat.

Thus, although the primary tumours of the breast are rationally to be considered as nothing else than diseased breasts or parts of the breast, which are still, to a certain extent, identical with or continuous with that organ of the body both structurally and functionally, yet from the point of view of their infectiveness, those tumours manifest an autonomy or individuality which entitles them to be considered as separate existences. But that individuality is not for every tumour of the breast one and indivisible; or it should rather be said that a tumour of the breast is not always one and indivisible. It is a diseased process extending to more or less of the mammary structure; but the issue of the diseased process is not necessarily the same at all points where the process is in force. In the first of the group of four cases described above, there were two kinds of secondary structure found in two different lymphatic glands. One of these wore the form of papillary outgrowths as if from the walls of acini, and the other resembled a collection of smaller acinous spaces lined with cubical epithelial cells with large nuclei. Now corresponding differences were found in different parts of the diseased mammary tissue, as they are indeed constantly found in the various centres of disease in the widely-extended mamma of the bitch. Each of those centres can be a source of infection and the case that has been referred to proves that such centres may exist quite close to each other and may each infect with its own type of structure different lymphatic glands lying in the same packet. That fact does not perhaps carry the analysis of the tumour-infective process much farther than it was before; but it appears to be a well-established fact, and has to be taken account of.

No. 6.

Further Researches on the Chemical Constitution of the Brain.

By J. L. W. Thudichum, M.D.

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I.—CONTINUATION OF THE STUDY OF THE PHOSPHORISED PRINCIPLES.

1. Chemolysis of Kephaline.

In the previous research (Rep. No. III., 1874, pp. 138 to 146,) it was found that when kephaline was boiled during some time with a solution of caustic soda or baryta, it was split up into simpler nuclei, which varied according to the nature of the alkali and the duration of its action. A preliminary description of these products was given, and it was proved that the phosphorus contained in kephaline was present in the form of *glycerophosphoric acid*. The baryum salts of *two fatty acids* were obtained, of which the one was soluble in ether, the other insoluble. But the nature of the *radicle containing the nitrogen* of kephaline was not elucidated, probably because the influence of the fixed alkalies destroyed the nitrogenised base almost as quickly as it was formed, so that ammonia and a small quantity of a nitrogenised base containing carbon were the only representatives of the presumably more complicated body. The chemolytic experiments on kephaline were therefore continued in a variety of ways, described in the following :—

Decomposition of Kephaline by Dilute Hydrochloric Acid.—The acid was chosen because it was hoped that it would fix the base when

once formed, and not allow it to be further chemolysed by heat and water. But this expectation was disappointed, as the acid solution, after some hours of boiling, yielded only ammonia, and no compound nitrogenised base; some glycerophosphoric acid was also isolated. The other products insoluble in water formed a mass, which, oily while hot, became solid on cooling, and was mainly a mixture of the fatty acids already alluded to. They dissolved, with the aid of ammonia, in hot water, and then furnished baryta salts, with barytic chloride, of which one portion was soluble in ether. This *soluble in ether* baryum salt was decomposed by means of ether and hydrochloric acid; the acid was again dissolved in ammonia water and transformed into a lead compound. This lead salt was also soluble in ether and contained 22·278 °/₀ of Pb. The portion of the *baryum salts insoluble in ether* was also transformed into lead salts, and was found to consist of *two lead salts*, of which the one was soluble, the other insoluble in ether. It was thus evident that the chemolysis by hydrochloric acid offered no advantages over the methods previously tried, and it was therefore not repeated.

Chemolysis of Kephaline Cadmic Chloride by Baryta.—In this experiment two sets of baryum salts were again obtained, one *soluble*, the *other insoluble in ether*. The salt which was soluble in ether furnished a lead salt, which was likewise soluble in ether (28·056 °/₀ Pb.), and insoluble in, and precipitated by, ether-alcohol. The salt which was insoluble in ether, when transformed into lead salt, was found to consist of two compounds, one insoluble in ether and in alcohol, the other soluble in ether, but precipitated from it by the addition of alcohol.

The barytic solution was freed from excess of baryta by carbonic acid, and the filtrate, after evaporation to a low bulk, was treated with absolute alcohol. A precipitate of barytic glycerophosphate was obtained, and identified by quantitative analysis. The alcoholic mother liquor was neutralised with hydrochloric acid, and precipitated with platinic chloride. The platinum salt so obtained was recrystallised from water, and ultimately obtained in brilliant plates and needles.

Analyses:—

(*a.*) 0·6760 grm. gave 0·2178 grm. platinum, and 0·9332 grm. argentic chloride = 32·219 °/₀ platinum and 34·149 °/₀ chlorine.

(*b.*) 0·5454 grm. gave 0·396 grm. CO_2 and 0·232 grm. H_2O = 19·801 °/₀ C and 4·726 °/₀ H.

(*c.*) 0·463 grm. gave 16·3c.c. normal nitrogen = to 4·404 °/₀ N.

Computation of Analyses:—

	Per-centages.	÷ At. Wgts.	÷ Pt = 1.
C	19·801	1·650	10·1
H	4·726	4·726	29·0
N	4·404	·314	1·9
O	4·701	·293	1·8
Pt	32·219	·163	1·0
Cl	34·149	·961	5·9

$= (C_5 H_{13} N O)_2 (H Cl)_2 Pt Cl_4$.

Neurine hydrochlorate platinic chloride, or $(C_5 H_{14} N O Cl)_2 Pt Cl_4$.

Besides the above salt, there was obtained from the alcoholic mother liquor from which it had been originally precipitated, a smaller quantity of a second crystallisable platinic salt. After recrystallisation from water it gave the following numbers on analysis:—

(*a.*) 0·3840 grm. gave 0·141 grm. Pt and 0·610 grm. Ag Cl = 36·718 °/₀ platinum and 39·297 °/₀ chlorine.

(*b.*) 0·7266 grm. gave 0·244 grm. CO_2 and 0·205 H_2O = 9·158 C and 3·134 % H.

(*c.*) 0·6234 grm. gave 27 c.c. N normal = 5·418 % N.

Computation of Analyses :—

	Per-centages.	÷ At. Wgts.	÷ Pt = 1.
C	9·158	·763	4·1
H	3·134	3·134	16·8
N	5·418	·387	2·0
O	6·275	·392	2·1
Pt	36·718	·186	1·0
Cl	39·297	1·107	5·9

$= (C_2H_7NO)_2(HCl)_2PtCl_4$, or $(C_2H_5NOCl)_2PtCl_4$.

This salt might be considered as dimethylamine, in which the third atom of hydrogen is replaced by hydroxyle, or as oxethylamine simply

$$\left.\begin{matrix} C_2H_5O \\ H \\ H \end{matrix}\right\} N$$

that is to say, a body formed from neurine, by the loss of three radicles of methyle and one of water.

A third base was also obtained; it was soluble in alcohol as platinic salt, giving the solution a brownish red colour, and on the addition of much ether was precipitated. It was purified by repeated solution in alcohol and reprecipitation by ether. Several grammes of this body which was precipitated in an oily state, but became solid on drying, were obtained. It was dried at 100° C. and analysed :—

(*a.*) 0·5392 grm. gave 0·2128 grm. Pt. and 0·7884 grm. Ag Cl = 39·466 % Pt. and 36·171 % Cl.

(*b.*) 0·5718 grm. gave 0·2520 grm. CO_2 and 0·168 grm. H_2O = 12·019 % C and 3·070 % H.

(*c.*) 0·4486 grm. gave 20 c.c. N at 15° C. and 749 mm. K H O col. = to 11·6 m.m. mercury = 5·019 % N.

Computation of Analyses :—

	Per-centages.	÷ At. Wgts.	÷ Pt
C	12·019	1·001	5·0
H	3·070	3·070	15·3
N	5·019	·358	1·79
O	4·255	·265	1·3
Pt	39·466	·20	1·0
Cl	36·171	1·018	5·0

leading to a formula $C_5H_{14}N_2O, HCl, PtCl_4$. This body, so anomalous in its constitution, has probably been derived from neurine molecules by duplication and subsequent decomposition. Such a condensation is observed upon the neurine molecules under the influence of oxydising agents.

Chemolysis of Kephaline by Baryta, with the view of identifying the base only.—The process was the same as in the former experiment. The platinum salt gave on analysis the following results :—

(*a.*) 0·5975 grm. gave 0·1902 grm. Pt and ·8282 grm. Ag Cl = 31·832 % Pt and 34·290 % Cl.

(*b.*) 0·5132 grm. gave 0·3760 grm. CO_2 and 0·2180 grm. H_2O = 19·981 % C and 4·719 % H.

(*c.*) 0·4438 grm. gave 16·8 c.c. N normal = 4·735 % N.

Computation of Analyses :—

	Per-centages.	÷ At. Wgts.	÷ Pt = 1.
C	19·981	1·665	10·3
H	4·719	4·719	29·3
N	4·735	·338	2·0
O	4·443	·278	1·7
Pt	31·832	·161	1·0
Cl	34·290	·966	6·0

$= (C_5 H_{13} N O)_2 (H Cl)_2 Pt Cl_4$, or $(C_5 H_{14} N O Cl)_2 Pt Cl_4$.

Decomposition of Kephaline by Baryta.—This experiment was undertaken upon a larger amount of kephaline than the previous ones. The kephaline was first warmed in water, whereby it swelled and dissolved to a paste, which was then boiled with two molecules of $Ba H_2 O_2$ in the ordinary way.

The baryum salts obtained in the earlier experiments were again found, and it was moreover observed that one of the fatty acids contained in them gave the purple reaction, which cerebrine also gives with sugar and sulphuric acid, and which resembles Pettenkofer's test for biliary compounds.

From the solution drawn off from the baryum salts of the fatty acids the excess of baryum was removed by $C O_2$, and the resulting filtrate concentrated by evaporation, and then treated with alcohol. The glycerophosphate of baryum thus obtained was converted into lead salt, and the lead salt into calcium salt ($C_3 H_7 Ca P O_6$).

The alcoholic mother liquor was freed from alcohol by evaporation, and the resulting solution after addition of nitric acid was precipitated by phospho-molybdic acid, and the product decomposed by hot $Ba H_2 O_2$. The yellow filtrate freed from the baryum that admitted of removal by $C O_2$, did yet contain baryum in combination. This was proved by combustion of the dried salt and analysis of the residue.

The concentrated solution of the base was freed from Ba by an equivalent amount of very dilute sulphuric acid, then neutralised by hydrochloric acid, and precipitated after concentration by alcoholic $Pt Cl_4$. The precipitate was recrystallised from water, 10 grammes being obtained in the shape of crystallised plates. The salt was dried and analysed :—

(*a.*) 0·910 grm. gave 0·299 grm. Pt and 1·2634 grm. Ag Cl = 32·85 °/₀ Pt and 34·34 °/₀ Cl.

(*b.*) 0·4770 grm. gave 0·3406 grm. $C O_2$ and 0·2130 grm. $H_2 O$ = 19·47 °/₀ C and 4·94 °/₀ H.

(*c.*) 0·0340 grm. gave by combustion in vacuo with Cu O and copper, 14·1 c.c. total gas normal. Of this 13 c.c. were $C O_2$ and 1·1 c.c. were N = to 4·04 °/₀ N.

Computation of Analyses :—

	Per-centages.	÷ At. Wgts.	÷ Pt = 1.
C	19·47	1·622	9·7
H	4·94	4·94	29·7
N	4·04	·288	1·7
O	4·36	·272	1·6
Pt	32·85	·166	1·0
Cl	34·34	·967	5·8

$= (C_5 H_{13} N O)_2 . (H Cl)_2 Pt Cl_4$, or $(C_5 H_{14} N O Cl)_2 Pt Cl_4$.

The alcoholic motherli quor from which this salt had been precipitated gave by precipitation with ether a quantity of the fluid oily salt, the

analysis of which has been given in a former paragraph ($C_5 H_{14} N_2 O$) $H Cl Pt Cl_4$, but it was very small in amount.

A third base was also obtained in small quantity by simple addition of much nitric acid to the original solution, after removal of glycero phosphate, and before precipitation with phospho-molybdic acid, and which gave the various alkaloidal tests.

Summary of results obtained in the various Chemolyses of Kephaline.—Kephaline may be regarded, considering its elementary composition and the products of its chemolysis, as a body in which two hydroxyls of the glycerine molecule are replaced by fatty acids (in part hitherto unknown), and in which the third hydroxyl is replaced by phosphoryl, which latter in its turn has one hydroxyl replaced by an ammonium base, thus :—

$$C_3 H_5 \begin{cases} \text{Fatty acid} \\ \text{Fatty acid} \\ H O (O P O) C_5 H_{13} N O. \end{cases}$$

The whole of the phosphorus is apparently contained in the radicle of glycerophosphoric acid, and in no other form. This body is first obtained on chemolysis, but being somewhat unstable, it is not difficult in the presence of bases to decompose it further into glycerine and phosphate of the base used.

The whole of the nitrogen appears to be present as neurine; the other bases which have been obtained being probably derived from neurine by secondary changes. This secondary decomposition would explain why the amount of the neurine obtained from a given weight of kephaline is less, sometimes much less, than the amount which they would lead us to expect.

Of the fatty acids contained in kephaline, various baryum, lead, and magnesium salts have been examined and analysed; but the results obtained do not yet justify the attempt of explaining their intimate relations. It is highly probable that the acid contained in the main soluble in ether, baryum, or lead salt, belongs to a series of acids containing at least one atom of oxygen more than the ordinary fatty acids; it possesses a power of absorbing oxygen, which makes its chemical manipulation a matter of the greatest difficulty.

**Note of an Essay on Glycero-phosphoric Acid and its Salts as obtained from the phorphorised Constituents of the Brain.*—The details of the data concerning glycerophosphoric acid from kephaline and other sources evolved in the course of this process, and certain additional matters, were communicated to the Chemical Society in a paper entitled: *On Glycero-phosphoric Acid and its Salts, as obtained from the phosphorised constituents of the Brain. By J. L. W. Thudichum and C. T. Kingzett*, printed in the second volume for 1876 of the Journal of the Chemical Society, p. 20, et seq. The paper consists of nine paragraphs. Of these the first contains an historical note; (2) a description of lead glycerophosphate; (3) a description and several analyses of normal glycerophosphate of calcium ($C_3 H_7 Ca P O_6$); (4) a description and analysis of acid glycerophosphate of calcium ($C_6 H_{16} Ca P_2 O_{12}$), here described for the first time; (5) glycerophosphate of baryum ($C_3 H_7 Ba P O_6$) from synthetically prepared acid, and from brain matters; also a hydrate, precipitated by alcohol ($C_3 H_7 Ba P O_6, H_2 O$); (6), the alcoholo-hydrated barytic glycerophosphate, containing probably at least three molecules of alcohol and six of water combined with one molecule of acid glycerophosphate; (7) In this paragraph the extraordinary features of this salt, which is new to

science, are compared with a few similar bodies known to science; but the authors say: "Glycerophosphate of baryum not only seems to be "the only organic compound which is known to form alcoholates, but "it is in so far unique (amongst inorganic and organic bodies) as it "forms a compound which is *an alcoholate* and *a hydrate* at the same time;" (8) is analytical, and relates to the instability of some glycerophosphates and the difficulty of burning their carbon entirely; (9) is a theoretical summary, exhibiting the constitution of the simplest phosphorised principles of the brain by the aid of four different formulæ.

2. Chemolysis of Amido-Myeline.

The body which formed the material for the following investigation was described in Report for 1874, No. III., new series, p. 179, as myeline cadmic chloride, and on analysis had given figures which led to the formula $C_{84}H_{165}N_3P_2O_{18},2CdCl_2$. It was there stated that it was possible or necessary to assume that it was a mixture or compound in atomic proportions of two bodies, one of which contains only one atom of N, while the other contains two atoms of N.

The process.

The compound on being placed in water swelled to a solid white jelly. It was then mixed with a solution of baryta containing what was calculated to be equal to three equivalents of the hydrate. The mixture was now boiled in a platinum still, with the view of condensing any volatile products, and collecting them in acidulated water. The boiling was continued during about 12 hours. There were obtained three different sets of products, (A) the baryum salts of several fatty acids, together with cadmic oxyde; (B) a solution of products containing nitrogenised matters, glycerophosphate and chloride of baryum; (C) a distillate combined with acid.

Products.

(A.) *The Baryum Salts of the Fatty Acids.*—They were decomposed with dilute hydrochloric acid in the presence of ether, and gave a dark-coloured ethereal solution (*a*) and a matter which assumed a gelatinous condition and remained insoluble (*b*).

(*a.*) *Examination of the Ether Extract.*—It was washed with water and distilled to dryness, the residue was dissolved in ammonia and much water. The hot filtrate was treated with solution of lead, whereby the acids were precipitated as lead salts. These were dried and treated with ether, when a white portion remained insoluble, while a coloured portion dissolved.

(*a.*) *The Soluble Lead Salts* were again decomposed by hydrochloric acid and ether, and then tranformed into baryum salts. On extracting these with ether, the greater part was found soluble in this agent, while a small portion remained insoluble and had a white colour.

(*a* 1.) *Insoluble* (*in Ether*) *Baryum Salt from Soluble* (*in Ether*) *Lead Salt.*—It was decomposed with hydrochloric acid, and furnished a fatty acid fluid below 25° C. It was reconverted into baryum salt, and this was boiled with alcohol. A portion dissolved, another portion remained insoluble in the boiling alcohol.

Portion Soluble in Boiling Alcohol.—The salt was deposited from the alcohol on cooling, and after drying at 100° C. it was analysed.

(*a.*) 0·343 grm. gave 0·117 grm. Ba SO_4 = 20·05 °/₀ Ba.

(*b.*) 0·3834 grm. gave 0·8352 grm. Co_2 and 0·3334 grm. H_2O = 59·411 °/₀ C and 9·662 °/₀ H.

Computation of Analyses :—

	Per-centages.	÷ At. Wgts.	÷ Ba = 1.
C	59·41	4·95	33·9
H	9·66	9·66	66·1
Ba	20·05	·146	1·0
O	10·88	·68	4·6

These figures approach the theory relating to margarate, 2 (C_{17} H_{33} O_2) Ba; but this compound is excluded by the solubility in boiling alcohol of the salt, and the low fusing point of the free acid. These features point indeed to oleic acid and oleate, but this is incompatible with the result of the analysis. The acid could not have been a homologue of oleic acid, on account of the deficiency of the oxygen. The analyses exhausted the whole quantity in hand, which did not exceed one gramme. The study of this body must therefore be resumed on a future occasion.

Portion Insoluble in Boiling Alcohol.—This salt fused in the boiling alcohol, but did not dissolve. After decomposition with acid and ether it yielded a fatty acid which fused at 18°, and on cooling became solid again at 17° C. The quantity of this body obtained was too small for analysis.

(*a* 2.) *The Soluble in Ether Baryum Salt* was precipitated from the ether by 85 °/₀ alcohol, and it was then redissolved and reprecipitated. Washed and dried at 100° C.

(*a.*) 0·5954 grm. gave 0·1446 grm. Ba S O_4 = 14·27 °/₀ Ba.

(*b.*) 0·3124 grm. gave 0·7274 grm. Co_2 and 0·2752 H_2O = 63·502 °/₀ C and 9·787 °/₀ H.

Computation of Analyses :—

	Per-centages.	÷ At. Wgts.	÷ B = 1.
C	63·502	5·2918	50·88
H	9·787	9·787	94·1
Ba	14·270	·104	1·0
O	12·441	·777	7·4

leading to the formula 2 (C_{26} H_{47} O_4) Ba. After this analysis the salt was again decomposed by H Cl and the free acid examined. It was solid at 18°, became softer between 25° and 30°, at 30° it was more mobile, and at 39° it entirely fused to a clear but coloured oil.

It was now converted into N H_3 salt, and this was transformed into lead salt, which was precipitated from its ethereal solution by alcohol and the dark salt again analysed.

(*a.*) 0·3858 grm. gave 0·6720 grm. C O_2 and 0·255 H_2O = 47·50 °/₀ C and 7·34 °/₀ H.

(*b.*) 0·2316 grm. gave 0·1106 grm. Pb S O_4 = 32·62 °/₀ Pb.

Computation of Analyses :—

	Per-centages.	÷ At. Wgts.	÷ Pb = 1.
C	47·50	3·958	25·2
H	7·34	7·34	46·7
Pb	32·62	·157	1·0
O	12·54	·783	4·9

leading to the formula C_{26} H_{46} O_5 Pb. During the transformation the acid had perhaps absorbed some oxygen, or had taken up a molecule of water and become dibasic. This increase of the basicity might also be a function of the lead, which has a great tendency to form basic compounds. For the purposes of the following considerations we may assume the acid to have had the formula C_{26} H_{48} O_4 or C_{25} H_{48} O_5. With sugar and sulphuric acid it gave the reaction characteristic of biliary acids, namely a deep purple colour.

By its composition also this acid approaches to and stands intermediate between certain biliary compounds, such as cholic acid cholesterine, and

Cholesterine	C_{26} H_{44} O
Myelocholic acid	C_{26} H_{48} O_4 (in baryum salt)
	C_{26} H_{48} O_5 (in lead salt)
Psychosine	C_{25} H_{49} O_8 N (see below)
Cholic acid	C_{24} H_{40} O_5

This relation is all the more striking as cholesterine, named from the bile, of which it is a normal ingredient, is also an ingredient of the brain, and that in much larger quantities than those in which it is found in the bile. But the comparison of quantities is of little value, as long as the function of the substance is not ascertained. The first aspect of these relations will, however, justify us in terming this new acid *myelocholic acid.*

(β.) *The lead salt insoluble in ether.*—This was again decomposed by hydrochloric acid in the presence of ether, and the colourless ethereal solution on distillation left a fatty acid fusing about 62—64° C. It was washed by successive meltings over pure water, and then by recrystallisation from dilute alcohol. This proceeding gave a large crop of wart-like crystals.

(α.) 0·1530 grm. gave 0·417 grm. CO_2, and 0·180 grm. H_2O = 74·33 °/₀ C and 13·06 °/₀ H.

Computation.

	Per-centages.	÷ At. Wts.	÷ 0 = 1.	
C	74·33	6·1941	7·87	×2
H	13·06	13·07	16·6	×2
O	12·61	·787	1·0	×2

$= C_{16} H_{32} O_2$

This analysis and its fusion point prove the acid to have been palmitic.

B. *Examination of the Solution filtered from the Baryum Salts of Fatty Acids.*

(α.) The excess of baryta was removed by CO_2, the filtrate concentrated and precipitated by alcohol. *The precipitate* consisted of chloride and glycerophosphate of baryum. These were separated by suitable means, and several salts of the glycerophosphoric acid prepared and analysed. Thus 0·3736 grm. of the normal calcium salt gave 0·2264 grm. $Ca_2 P_2 O_7$ on ignition = 60·59 °/₀ calcium; theory requires 60·47 °/₀ Ca.

(β.) *The alcoholic solution* was freed from alcohol by evaporation, rendered acid, and precipitated by phospho-molybdic acid. The precipitate so obtained was then decomposed with hot baryta water; the excess of baryum was removed by CO_2, and the resulting solution after neutralisation with hydrochloric acid was evaporated to dryness on a water bath. On extracting the residue with absolute alcohol baric chloride remained insoluble, while the alcoholic filtrate gave with platinic chloride a yellow salt which was recrystallised from water. These crystals were thin rhombic plates, and on analysis gave the following numbers:—

Isolation of the alkaloid.

(α.) 0·471 grm. gave 0·3304 grm. CO_2, and 0·198, H_2O = to 19·131 °/₀ C and 4·67 °/₀ hydrogen.

(b.) 0·7746 grm. gave 0·2506 grm. Pt and 1·0836 AgCl = 32·352 °/₀ Pt and 34·636 °/₀ Cl.

(c.) 0·0536 grm. gave by combustion in vacuo with CuO and copper, 1·8 c.c. N normal, showing 4·201 °/₀ N.

Computation of analyses:—

	Per-centages.	÷ At. Wgts.	÷ Pt. = 1.
C	19·131	1·5942	9·7
H	4·670	4·670	28·6
N	4·201	·300	1·8
O	5·140	·321	1·9
Pt	32·252	·163	1·0
Cl	34·606	·974	6·0

$= (C_5 H_{13} N O)_2 (H Cl)_2 Pt Cl_4$ or $(C_5 H_{14} N O Cl)_2 Pt Cl_4$.

C. *Examination of the Distillate from the Chemolysis.*

(*α.*) The distillate was strongly alkaline and had an odour of triethylamine; it was redistilled and the product neutralised with very dilute sulphuric acid. This solution was evaporated to dryness on the water bath, and on extraction with absolute alcohol, there was left an insoluble white salt, which when dry weighed less than 1 grm., and was proved by analysis to consist of sulphate of ammonium.

0·0218 grm. dried at 80° C. gave by combustion in vacuo with oxyde of copper and metallic copper, 3·70 c.c. N normal = 21·23 °/₀ N; theory requires 21·21 °/₀.

(*β.*) *The alcoholic extract* gave with alcoholic Pt Cl_4 a small quantity of salt, which was recrystallised from water, and weighed when dry less than 0·5 grm. It was probably the platinum salt of a volatile base.

The products which have been described in the foregoing may be considered as the more simple products of the chemolysis; some of them, such as the fatty acids, are final, inasmuch as they cannot be changed by a continued influence of the alkali under the same conditions. Others, such as the glycerophosphoric acid, would change but little by continued action of excess of baryta; the nitrogenised body, however, would be entirely destroyed by a long continuance of this influence. It is therefore necessary to interrupt the process before any newly-formed nuclei are entirely destroyed, and this entails the necessity of leaving some portions of the original matter imperfectly chemolysed. Of this kind was the matter which when the baryta salts of the fatty acids were decomposed by hydrochloric acid and water in the presence of ether, remained suspended in the water as a gelatinous mass. (*See* A *b.*)

(*b.*) *The gelatinous mass* just alluded to was found to consist of four different bodies, which were separated from each other in the following manner. It was dissolved in hot alcohol; this deposited a crystalline body on cooling (*α β* and *γ*), and kept another in solution *δ*. The matter recrystallised from alcohol was again treated with hot alcohol, and now it did dissolve only partially; that which dissolved was reprecipitated on cooling, whilst that which did not dissolve fused like cerebroconote.

Differentiation of the gelatinous mass. Three new bodies.

(*α.*) *Analysis of deposited matter after drying at* 80° C.:

(*a.*) 0·0238 grm. gave by combustion in vacuo with Cu O and Cu 0·39 c.c. N normal = 2·05 °/₀ N.

(*b.*) 0·3334 grm. gave 0·8562 grm. $C O_2$ and 0·3616 grm. $H_2 O$ = 70·03 °/₀ C and 12·04 °/₀ H.

(*c.*) 1·0374 grm. gave 0·1222 grm. $Mg_2 P_2 O_7$ = 3·289 °/₀ P.

Computation of analyses:—

	Per-centages.	÷ At. Wgts.	P = 1.
C	70·03	5·836	55·0
H	12·04	12·04	113·0
N	2·05	0·146	1·3
P	3·289	0·106	1·0
O	12·591	0·786	7·4

= $C_{55} H_{113} N P O_7$ Palmito-myeline.

Further on we shall return to the study of this substance with the view of elucidating its constitution.

(*β.*) That part of the matter which fused in the alcohol and remained insoluble was soluble in benzene, from which it was reprecipitated by alcohol as a plastic precipitate.

On placing this in ether part dissolved and part remained insoluble. That which remained insoluble (γ) was preserved for investigation in the future; while the ether solution was precipitated by alcohol in a snow-white flaky form. It was dried at 100° C. and analysed.

(a.) 0·3680 grm. gave 0·7434 grm. $C O_2$ and 0·3196 $H_2 O = 55·02\%$ C and 9·64 °/₀ H.

(b.) 0·0378 grm. gave 0·6 c.c. N normal (on combustion in vacuo with Cu O and Cu) = 1·98 °/₀ N.

(c.) 0·0285 grm. gave 0·5 c.c. N normal = 2·19 °/₀ N.

(d.) 0·9360 grm. gave 0·178 grm. $Ba S O_4 = 11·17\%$ Ba and 0·160 grm. $Mg_2 P_2 O_7 = 4·78\%$ P.

Computation of analyses:

	Per-centages.	÷ At. Wgts.	÷ Ba = 1.
C	55·02	4·585	56·5
H	9·64	9·64	118·5
Ba	11·17	0·081	1·0
N	2·08	0·148	1·8
P	4·78	0·154	1·9
O	17·31	1·081	13·3

$= C_{57} H_{118} Ba N_2 P_2 O_{13}$.

This was therefore a salt of baryum which had, probably owing to its peculiar physical condition, escaped decomposition by hydrochloric acid.

(δ.) *Examination of the alcoholic mother liquor:*

The mother liquor from the bodies described under α, β, and γ was concentrated, and made small deposits at various stages, and finally on cooling precipitated a matter which dissolved in ether. The ethereal solution was mixed with much alcohol, and the solution precipitated by alcoholic lead acetate. The precipitate was washed, isolated, dried at 100° C, and analysed.

(a.) 0·3904 grm. gave 0·323 grm. $C O_2$ and 0·191 $H_2 O = 22·566\%$ C and 5·435 °/₀ H.

(b.) 0·4904 grm. gave 0·2658 grm. $Pb S O_4 = 36·65\%$ Pb and 0·1214 grm. $Mg_2 P_2 O_7 = 6·843\%$ P.

Computation of analyses:—

	Per-centages.	÷ At. Wgts.	÷ Pb 1.
C	22·566	1·8805	10·6
H	5·435	5·435	30·7
Pb	36·650	·177	1·0
P	6·843	·220	1·2
O	28·506	1·781	10·0

leading to the formula $C_{11} H_{30} Pb P O_{10}$.

Secondary chemolysis of $C_{55} H_{113} N P O_7$ (palmito-myeline).

A quantity of this intermediate product was made into a thin paste with water, and two equivalents $Ba H_2 O_2$, and the whole heated to 130° C. during three hours in a closed platinum tube. Attention was only directed to the solid baryum salts in this experiment, nothing being contained in the baryta solution. They were decomposed with H Cl and ether, and the ether solution decanted and the mother liquor rejected. On now washing the ethereal solution with water a phosphorised matter was obtained as a precipitate. This was isolated, washed, and recrystallised from alcohol, then analysed.

(a.) 0·2458 grm. gave 0·581 grm. CO_2 and O ·2604 grm. $H_2 O$ = 64·46 °/₀ C and 11·77 °/₀ H.

(b.) 0·0434 grm. gave by combustion in vacuo with Cu O and C 0·84 cc. N normal = 2·42 °/₀ N.

(c.) 0·6594 grm. gave 0·1000 grm. $Mg_2 P_2 O_7 = 4·235\%$ P.

Computation of analyses :—

	Per-centages.	÷ At. Wgts.	÷ P = 1
C	64·46	5·371	39·4
H	11·77	11·77	86·5
N	2·42	·172	1·2
P	4·23	·136	1·0
O	17·12	1·07	7·8

$= C_{39} H_{86} N P O_8$.

The Ether extract was distilled and the free fatty acid contained in it converted first into ammonium salt, and then into baryum salt insoluble in ether. The latter was then decomposed and the free fatty acid analysed. Its fusion point was near to that of ordinary palmitic acid; ·1712 grm. gave 0·4400 grm. CO_2 and 0·2000 grm. H_2O = 70·09 % C and 12·98 % H.

	Per-centages.	÷ At. Wgts.	÷ C = 16.
C	70·09	5·840	16
H	12·98	12·980	35·5
O	16·93	1·058	2·9

That is to say it was palmitic acid imperfectly dried before analysis, $C_{16} H_{32} O_2 + H_2 O$.

The two bodies produced by the chemolysis of $C_{55} H_{113} N P O_7$ may have been obtained by this reaction: $C_{55} H_{113} N P O_7 + 3 H_2 O = C_{39} H_{86} N P O_8 + C_{16} H_{32} O_2$. No glycerophosphoric acid or neurine or any other fatty acid resulted from this chemolysis.

Summary of Results.—The body described as amido-myeline, and which had given the formula $C_{84} H_{165} N_3 P_2 O_{18}$, 2 Cd Cl_2 on chemolysis by baryta hydrate has been split up into more simple parts, of which some are intermediate, others ultimate products of the process.

(Aa 1) $C_{17} H_{34} O_2$, *margaric acid*, analysed in the shape of a baryum salt, 2 ($C_{17} H_{33} O_2$) Ba, and an insoluble (stearoconotised) body.

(Aa 2) $C_{26} H_{48} O_4$, or $C_{25} H_{48} O_5$, *myelocholic acid*, in the shape of a baryum salt, 2 ($C_{26} H_{47} O_4$) Ba, and in the shape of a lead salt prepared from the baryum salt, of the formula $C_{26} H_{46} O_5$ Pb.

(Aa β) $C_{16} H_{32} O_2$, *palmitic acid*, analysed in the free state.

(B) $C_3 H_9 P O_6$, *glycerophosphoric acid* analysed as calcium salt, $C_3 H_7$ Ca P O_6.

(Bβ) $C_5 H_{15} NO_2$, *choline* or *neurine* analysed in the shape of chloride platinic chloride ($C_5 H_{14} N O Cl)_2 Pt Cl_4$.*

(C) NH_3, *ammonia* analysed as sulphate.

(Cβ) *an organic volatile base*, obtained as chloride platinic chloride, not analysed.

The following were the products which maybe termed intermediate:—(A b) $C_{55} H_{113} N P O_7$, palmitomyeline; (A b β) $C_{57} H_{118} N_2 P_2 O_{13}$ Ba, a compound which has been examined as baryum salt. (A b δ) $C_{11} H_{32} P O_{10}$, P b, a body which has been analysed as lead salt.

* The formula of $C_5 H_{15} N O_2$ is rather presumed than proved as regards the exact quantity of the hydrogen and oxygen; for if the H Cl were like the Pt Cl_4 merely an addition, then the formula of the free base would be $C_5 H_{13} NO$; but if the chloride were a product by substitution of hydroxyl by Cl, and expulsion of the hydroxyl as H_2O, then the larger formula for the free body would be correct. Some assume the existence of two bodies of the formulæ which compete in the foregoing consideration and term the one choline or neurine, the other oxycholine or oxyneurine.

The palmitomyeline on secondary chemolysis gave a body—(A b α 1) C_{39} H_{86} N P O_8, showing a composition very near to the simplest form of myeline. But as it escaped chemolysis by baryta, it is difficult to assume that it should have the intrinsic constitution of this body, and (A b α 2), C_{16} H_{32} O_2, + H_2 O, palmitic acid imperfectly dried before analysis.

We have, therefore, here 12 different bodies, obtained by chemolysis from the primary cadmium salt, of which several are new to chemical science. Some may be assumed to be imperfectly chemolysed intermediate products, or perhaps, but not very probably, bodies formed anew by synthesis. But myelocholic acid is a definite and round radicle, and in that quality becomes a great difficulty in the way of theoretical considerations concerning the structure of the chemolysed compound. I therefore judge it best not to attempt the formation of a structural formula for the amido-myeline cadmic chloride body, but to leave this for a time when the above empirical results shall have been confirmed, amplified, or corrected by repetition and extension.

* *Note of an essay on Hemine, Hematine and a Phosphorised Principle resembling Amido-myeline contained in the Blood.*—The account of this body is given in a research carried out in the Pathological Laboratory, and read before the Chemical Society, and published by that Society in their Journal for September 1876, p. 255 *et seq.*, under the title: *On Hemine, Hematine, and a Phosphorised substance contained in Blood Corpuscles.* By J. L. W. Thudichum and C. T. Kingzett. (Paragraph 1) on the composition of crystallised hemine, fixes the material to have been the one described in the 11th Report of the Medical Officer of the Privy Council, 1869, p. 155, and shows it to have contained 7·6 °/₀ of iron as an essential constituent, nearly 3·°/₀ chlorine, giving no ratio for assuming the compound to be either neutral or basic, and about 0·6 °/₀ phosphorus, showing the crystals to be contaminated with a phosphorised body. (2.) In this section the attempt to saturate the hemine crystals with H Cl is described, and the results are given. (3.) In this paragraph the action of nitric acid on hemine is described, and the statements of Preyer concerning this reaction are refuted. (4.) The action of sulphuric acid on hemine is given, and shown to consist in the production of cruentine, first described in Medical Officer's Report, 1867, p. 228, and 1868, p. 161. The next paragraph (5) describes experiments intended to effect the extraction of iron from hemine, with a view of testing the statements of C. Paquelin and L. Jolly, Comptes Rendus, 79 (1874) 918, to the effect that pure hematine contained no iron. Their processes were first repeated, and then further criticised by experiments. These are given in paragraph (6) action of acetic and citric acids on hemine, and (7) hematine, benzene, and acetic acid. These experiments lead the authors to a very pure hematine, which *contained more iron than has ever before been found in any preparation of hematine*, namely, 9·08 °/₀. The complete analysis of this body leads the authors to the new formula C_{32} H_{32} Fe N_4 O_6 as that of hematine. (8.) In this paragraph the isolation, purification, and analysis of the phosphorised body from the hemine crystals are described. The analyses lead to C_{76} H_{164} N_3 P_2 O_{14} $(Cd\ Cl_2)_2$ and furnish remarkable evidence of the identity of this principle with one obtained from the brain. (Report Medical Officer, New Series, No. III., 1874, p. 174.)

3. Chemolysis of Lecithine.

In my first report on the Chemical Constitution of the Brain (New Series, No. III., p. 180) I pointed out that "lecithine when isolated in

"the only form in which it can at present be separated from the other "brain-matters, namely, as platinic chloride hydrochlorate salt, im- "mediately after isolation begins to decompose, and completes this "decomposition during the steps necessary for its purification." Its platinum salt, which is in the first instance soluble in ether, becomes in the air or in the vacuum speedily covered with oily drops (oleic acid), and the residual salt is then insoluble in ether.

It was upon such changed platinic salt insoluble in ether that the following chemolysis was effected :—

Water alone was found capable of removing at least some of the platinic chloride, but this treatment was not persisted in, and the salt was boiled with two molecules of $Ba\,H_2\,O_2$ during two hours. The decomposition was effected very readily, a black precipitate (of platinum) being formed simultaneously and insoluble baryum salts of certain fatty acids.

Examination of the Baryum Salts.—These were washed with water and then decomposed by hydrochloric acid, in the presence of ether. The ether solution was distilled to dryness and the residual matter converted into ammonium soap, and the latter in its turn was converted into baryum salt once more, and after drying extracted with much boiling absolute alcohol. The alcoholic extraction was continued to perfection.

The extracts deposited a white salt on cooling, which was isolated, dried, and analysed :

(*a.*) 0·1792 grm. dry at 100° C. gave 0·0596 grm. $Ba\,SO_4$ = 19·55 °/₀ Ba. Oleate of baryum requires 19·59 °/₀ Ba. This salt was therefore *oleate of baryum*.

The baryum salt left undissolved by the alcohol was insoluble in ether. It was once more decomposed by hydrochloric acid in the presence of ether, and converted first into ammonium soap, and again into baryum salt. It was now isolated, dried at 100° C., and analysed :—

(*a.*) 0·1922 grm. gave 0·0648 grm. $Ba\,SO_4$ = 19·82 °/₀ Ba.

(*b.*) 0·2342 grm. gave 0·4960 grm. $C\,O_2$ and 0·208 grm. $H_2\,O$ = 57·76 °/₀ C and 9·86 °/₀ H.

Computation of Analyses :—

	Per-centages.	÷ At. Wgts.	Ba = 1.
C	57·76	4·813	33·4
H	9·86	9·86	68·4
Ba	19·82	·144	1·0
O	12·56	·785	5·4

$= C_{17}\,H_{33}\,ba\,O_{2\cdot7}$.

This was, therefore, apparently *margarate of baryum*, or a salt of a new acid, $C_{17}\,H_{34}\,O_3$, *oxymargaric acid*.

Examination of the Baryta solution.—The excess of baryta was first removed from the solution by means of carbonic acid, and then nitric acid was added to strong acidity. In this state the solution was precipitated by phosphomolybdic acid, and the filtrate reserved. The precipitate was decomposed by hot baryta and concentrated to a low bulk. The baryum which still remained in combination with the base was carefully removed by the exact amount of sulphuric acid necessary, and after concentration the resulting solution was neutralised by H Cl and precipitated by alcoholic $Pt\,Cl_4$. The platinic compound crystallised from water in long prismatic needles, which proved on analysis to have the same composition as the ammonium base from kephaline, but which crystallised in lustrous plates.

App. No. 6.

On the Chemical Constitution of the Brain, by Dr. Thudichum.

The quantity of the platinum salt obtained was very near to that which should have been obtained, assuming all the nitrogen to exist in one form in lecithine, and to be obtained in one form.

(*a.*) 0·8900 grm. gave 0·2830 grm. Pt and 1·2368 grm. Ag Cl = 31·797 °/₀ Pt and 34·376 °/₀ Cl.

(*b.*) 0·455 grm. gave 0·3158 grm. CO_2 and 0·1920 H_2O = 18·92 °/₀ C and 4·68 °/₀ H.

(*c.*) 0·0324 gave by combustion in vacuo with CuO and copper 1·2c.c. N normal = 4·63 °/₀ nitrogen.

Computation of Analyses:—

	Per-centages.	÷ At. Wgts.	÷ Pt – 1.
C	18·92	1·576	9·78
H	4·68	4·68	29·00
N	4·63	·330	2·00
O	5·61	·350	1·00
Pt	31·79	·161	6·00
Cl	34·37	·968	2·1

$= (C_5 H_{13} NO)_2 (HCl)_2 Pt Cl_4$.

The filtrate separated from the phospho-molybdic acid precipitate of the base was found to contain glycerophosphoric acid. The chemolysis of lecithine therefore is complete as there were obtained—

Oleic acid - -	$= C_{18} H_{34} O_2$
Margaric acid -	$= C_{17} H_{34} O_2$ (or oxymargaric $C_{17} H_{34} O_3$?)
Glycerophosphoric acid	$C_3 H_9 P O_6$
Neurine - -	$= C_5 H_{13} N O$ (or $C_5 H_{15} N O_2$?)
Total - -	$= C_{43} H_{90} N P O_{11}$
Deduct -	$= H_6 O_3$ entered in chemolysis
Leaves -	$= C_{43} H_{84} N P O_8$ = lecithine.

The constitution of the body may be thus expressed:—

$$C_3 H_5 \begin{cases} C_{18} H_{33} O_2 \\ C_{17} H_{33} O_2 \\ OH\,(OPO)\,C_5 H_{13} NO \end{cases}$$

The formula which Strecker constructed for the lecithine he isolated from the yelks of eggs, was $C_{42} H_{84} NPO_9$ and, the body gave on chemolysis glycerophosphoric acid, cholin ($C_5 H_{15} NO_2$), oleic acid ($C_{18} H_{34} O_2$), and palmitic acid ($C_{16} H_{32} O_2$), which he, however, termed "*margaric*." Thus great similarity in composition is exhibited between brain and egg lecithine.

Note on oleic acid.

* *Note on Oleic Acid.*—Oleic acid is generally considered to have much affinity for oxygen, so as greatly to impede attempts to obtain it in a pure state. This absorption of oxygen is considered and stated to be attended with the production of a brown colour, and a change in the nature and properties of the acid.

Pure oleic acid, prepared expressly from oil of almonds, with the view of comparing it with the oleic acid furnished by lecithine, showed none of these properties. The potash, ammonium, lead, and baryum salts were all white and showed no tendency to become coloured on exposure. The free acid was also free from this tendency and was only very faintly yellow, while its solution in ether was colourless and did not become brown on exposure. To prove the purity of the body the baryum salt was analysed for baryum and found to contain 19·73 °/₀ as against 19·60 °/₀ required by theory.

The chemistry of oleic acid and bodies nearly allied to it requires much study before such absolute and categorical statements can be made about it as those which are met with in many chemical handbooks. Many of these statements are misleading, and arise no doubt from a want of acquaintance with the subject on the part of the authors. To quote one out of a number. In Hofmann's (Prof. in Gratz) Physiological Chemistry the oleate of baryum, a diagnostic salt, is described as "shooting out in crystals" from a hot alcoholic solution. I do not believe that any chemist can obtain this salt in any other form than that of a very fine white powder, and in a great number of operations I have never obtained it in any other. I can fully confirm the description of the appearance and solubility of this salt given by Berthelot.

(4.) *Bases existing in the Brain in combination with Kephaline and Myeline.*

In the first part of these researches, New Series, No. III., 1874, p. 129, it was stated that the kephalines (and myelines) as they exist in brain matter, and as isolated therefrom, are associated with certain bases, by a power of combination derived from their acid character. These bases can only be removed and the principles obtained in a pure state by dissolving the compounds in water, and adding hydrochloric acid, which combines loosely with the principles on account of their alkaloidal character, to the exclusion of the bases, which then pass into solution as chlorides. From the kephaline hydrochlorate the hydrochloric acid can be removed by much water alone, and then on dissolving the kephaline in ether and reprecipitating it by alcohol, it is obtained pure.

In order to obtain some knowledge regarding the relative amounts and nature of the bases in combination with the phosphorised constituents of brain-matter, a quantity of solution obtained by the hydrochloric acid process, above described, and which was derived from kephaline and myeline, was submitted to analysis.

It was evaporated to dryness and the residue ignited in a previously weighed platinum dish. During this ignition much chloride of ammonium was given out, and its nature distinctly proved by condensing and analysing it.

The fused mass was dissolved in dilute hydrochloric acid, and the solution so obtained treated with excess of ammonia. The white gelatinous precipitate which was thrown down was scarcely coloured black by sulphide of ammonium. The precipitate and filtrate were submitted to qualitative and quantitative analysis.

Examination of precipitate.—The colouring matter was evidently sulphide of iron, but it did not amount to more than a trace. [The *original* solution had been subjected in a neutral state to a current of sulphuretted hydrogen with the object of removing some platinum that had been used along with the hydrochloric acid, as $PtCl_4$, in the precipitation of the kephaline and myeline from the aqueous solutions. This treatment must therefore have removed any copper and iron which were undoubtedly present.]

The precipitate was dissolved in dilute hydrochloric acid, and the calcium, magnesium, and phosphoric acid estimated as follows:—

The solution was nearly neutralised by sodic carbonate, after addition of some ferric chloride, and then an excess of pure barytic carbonate added, shaken, allowed to stand, and then filtered.

From the concentrated filtrate the baryum was removed by sulphuric acid, and the filtrate was then precipitated in the presence of

ammonia by oxalate of ammonium. The oxalate so obtained was converted by intense ignition into oxide which weighed 0·1994 grm. Ca O = 0·1423 grm. calcium.

The filtrate and washings from the calcic oxalate were treated as ordinarily in cases where it is desired to estimate magnesium, and there was obtained 0·5555 grm. $Mg_2 P_2 O_7$ = 0·1212 grm. magnesium.

The precipitate which had been produced by ferric chloride, and sodium and baryum carbonates, was dissolved in nitric acid, and the phosphorus estimated by the combined molybdate and magnesium methods. This gave 0·3266 grm. phosphorus = 0·7480 grm. phosphoric acid ($P_2 O_5$).

Examination of filtrate.—This was proved to be free from magnesium and calcium. The potassium contained in it was estimated in the usual way by means of platinic chloride, giving 11·2766 grms. of 2 K Cl, $Pt Cl_4$ salt = 3·651 grms. K Cl = 1·911 grms. potassium. The mother liquor and washings were evaporated to dryness, and the platinum was removed by extracting the ignited mass with water acidified by hydrochloric acid. The extract so obtained was evaporated to dryness and fused; the residue weighed 3·45 grms. (Na Cl) = 1·356 grm. sodium. The quantities of potassium and sodium thus found were controlled by the analysis of a separate part of the original solution containing their chlorides, and calculating from the residue obtained on evaporation, there should have been found—

A total quantity of chlorides = 7·09 grms.

There was found K Cl = 3·651 „
and Na Cl = 3·450 „
or a total of = 7·101 „

Distribution of the Bases and Phosphoric Acid.—Assuming the calcium and magnesium to have originally existed as tribasic phosphates, and any phosphoric acid remaining over to have been in combination with potassium, then we have—

Ca	= 0·1423 grm.	existing as	3 Ca O, $P_2 O_5$
Mg	= 0·1212 „	„	3 Mg O, $P_2 O_5$
K	= 0·5663 „	„	3 K_2 O, $P_2 O_5$
K	= 1·3447 „	„	combined directly with kephaline and myeline.
Na	= 1·356 „	„	
P	= 0·3266 „	„	$P_2 O_5$ (0·748 grm.) and distributed between the Ca, Mg, and K.

It has been proved in the first research (l. c. p. 130) that kephaline was partly in combination with calcic oxyde, or lime, uncombined with any other acid. In the present research we find that there may be in kephaline (and myeline) even a much greater quantity of potash and soda in direct combination than of lime. Both observations supplement each other, the first one being qualitative only, the present research stating the quantities of the bases relatively to each other.

II.—CONTINUATION OF THE STUDY OF THE NITROGENISED PRINCIPLES.

1.—Introduction.

In the first Report of Researches on the Chemical Constitution of the Brain (New Series, No. III., 1874, p. 182 *et seq.*) I have shown that the nitrogenised ingredient peculiar to the brain, free from phosphorus and sulphur, formerly termed cerebrine, actually consisted of at least three bodies, or perhaps groups of bodies, the cerebrines, phrenosines, and kerasines, of each of which one representative had been isolated and analysed, namely, cerebrine $C_{34}H_{66}N_2O_8$, phrenosine, $C_{34}H_{67}NO_8$, and kerasine $C_{46}H_{91}NO_9$. The isolation was effected by fractional precipitation, partly from alcoholic solutions by cooling, partly from the same solutions by the employment of plumbic acetate.

Some of the pure substances were subjected to the influence of chemolytical agents, with a view of learning something about their chemical constitution. Thus phrenosine by being boiled with alcohol and a little sulphuric acid, was changed in a manner so as to show an increase in the carbon as compared to the nitrogen, or better it yielded up a portion of its nitrogenised nucleus. A body soluble in cold absolute alcohol was formed, perhaps the psychosine of the following research. On being boiled with water acidulated with sulphuric acid, phrenosine gave a body which reduced alkaline copper solution, among other products left unstudied. This indicated the probability of the formation of sugar, which had already been observed by Liebreich when he decomposed his protagon with hydrochloric acid. A body similar to sugar in its chemical composition was also obtained by Otto from the body termed by him cerebrine, and believed to be free from nitrogen. (See Report, 1874, p. 242.) The syrup obtained from the hydrochloric acid employed reduced cupric solution, and gave a precipitate with basic acetate of lead which turned red on heating. The analyses of the syrup gave 41·7 °/₀ C, and 7·32 °/₀ H, but did not lead the author to identify his product with sugar, which contains 40 °/₀ C, and 6·6 °/₀ H.

I next observed that when phrenosine was heated by itself to about 160° it fused, became dark, and evolved water with ebullition, just as sugar does when it passes into caramel. This phenomenon supported the surmise of the presence in these bodies of a radical closely related to and capable of transformation into sugar. The striking affinity of the nitrogenised principles for water, by means of which they swell in hot water like starch on being boiled, seemed also to point in a similar direction, namely, to the presence of a starch radicle which might determine this swelling capacity; but as the phosphorised matters had a similar though less pointed property, and were known not to yield any sugar on chemolysis, this property was not considered as an important guide to the inquiry.

As sugar had been obtained from so-called protagon, which is now admitted to have been a mixture of several phosphorised with several nitrogenised principles, and from a matter free from phosphorus, and supposed to be free from nitrogen, but in which the nitrogen had probably been overlooked, I judged that the experiment might be repeated with even better chance of success upon those mixtures of cerebrine and phrenosine, which are obtained in the form of the earlier precipitates in the course of the fractional precipitations employed for

isolating the pure principles. And I further hoped that the chemolysis of these cerebrine bodies, which had no very marked basic or acid properties, and showed an indifference towards acids and bases similar to that shown by so-called nitriles or imides, might produce simpler radicles of more decided combining propensities, being either acids or alkaloids, and therefore easier to seize and study. I also hoped that, as in the case of the phosphorised substances, one or more radicles might be found to be common to all the cerebrine bodies, and be the cause or causes of the identity of the reactions, which like the purple with sulphuric acid and sugar, they all uniformly exhibit. And I expected that if these simpler products could be obtained in quantity from these mixed materials, they might help to find means for a complete separation of all the matters and for the formation of their structure formulæ, in the same manner as the chemolysis of the mixed phosphorised bodies has led to the discovery of their fundamental and uniform radicles, and has thereby greatly aided the elucidation of their differences.

These expectations have been to a large extent fulfilled, although the researches are not yet by any means completed. Five classes at least of bodies have been obtained from cerebrine and phrenosine by chemolysis, both with acids and alkalies. Of these one, *sugar*, already previously known, has now been determined as actually formed by chemical reactions not only, but by optical test and quantitative analysis. A second body, an alkaloid, *psychosine*, is new to chemical science, and for the first time described in this research. *Three new acids*, forming baryum salts, some containing nitrogen, some free from it, await further study. Other matters isolated may be intermediate products; others, again, products of the secondary chemolysis of the five bodies isolated and identified. Among the latter is a *volatile alkali*, obtained under circumstances which do not yield psychosine, and an *amorphous acid* soluble in water, obtained when sugar is not obtained, because the chemolytic acid probably transforms both psychosine and sugar into simpler products when its influence is continued longer or becomes more energetic with the aid of higher temperature and pressure. For effecting chemolysis sulphuric acid on the one, and baryta hydrate on the other, were alone employed, as being those reagents which can be most easily and completely removed from the new products.

2.—Chemolysis of Cerebrine and Phrenosine by Baryta.

(*a.*) *Attempt to isolate the Nitrogen Nuclei in Cerebrine and Phrenosine.—Series I.*

Experiment I.—The preparation selected for this experiment was "prep. 1314," being the first hour's deposit from first hour's cerebrine from ox W.M. On examination it was found to contain a small proportion of phosphorus (in all probability as myeline). When freed from this the body may be considered as a mixture of one molecule of cerebrine with two molecules of phrenosine, since on analysis it yielded the formula $C_{48}\ H_{94}\ N_2\ O_9$ (*see* Report, New Series, No. III., 1874, p. 185).

40 grammes of this preparation, together with 80 grammes $Ba\ H_2\ O_2$ and sufficient water to form a paste were enclosed in glass tubes, which were then hermetically sealed and heated to 135° for several hours, after which the tubes were broken and their contents removed, the solid matter separated by filtration and washed with water until free from excess of $Ba\ H_2\ O_2$. The portion insoluble in water was in this

experiment at once decomposed by means of H Cl in presence of ether and water, the ether extract distilled to dryness; the residue so obtained dissolved in water containing NH_3, and this solution heated with $BaCl_2$ in excess. The reconstituted baryum salts thus obtained were next extracted with alcohol and ether till each of these solvents ceased to take up any further quantities.

The alcohol and ether extracts were proved to contain baryum salts of fatty acids in small quantity, and the final insoluble larger quantity of matter after extraction with alcohol and ether was shown to be a baryum salt of an amidated fatty acid. The analysis of this latter and other salts are withheld until such time when the connexion between them and their relation to the original molecule are more evident.

The aqueous solution was proved to contain matters of a basic character in small quantity, and these were studied, as far as material would permit, with regard to their behaviour to such reagents as phospho-molybdic acid, &c.

The results of this pioneering experiment may be stated to be as follows:—The body under examination yielded when chemolysed with BaH_2O_2 in sealed tubes for several hours at 135°, some unchanged cerebrine, a base or bases soluble in water, small quantities of baryum salts soluble (1) in alcohol, (2) in ether, (3) in alcohol and ether, and finally a considerable quantity of an insoluble baryum salt of an amidated fatty acid.

Experiment II.—The preparation used was that described under Experiment I., but the mode of procedure observed somewhat different, viz., the temperature of the sealed tubes was not kept constant at 135°, but allowed to fall as low as 100° during the operation, and the heating was continued for a less period of time.

50 grammes of the preparation, together with 100 grammes BaH_2O_2 and 50c.c. of water were employed. After removal of the contents of the tubes and washing of the solid matter free from excess of BaH_2O_2, the portion insoluble in water was at once extracted with alcohol of 85 %, and finally with ether. All products appeared in the first instance similar to those of the first experiment, but on a final evaporation of the concentrated alcoholic mother-liquors from the several extractions, after these had been allowed to deposit on cooling, a residue was obtained varying markedly in character from the parallel product of the previous experiment.

On examination of this body it was found to be insoluble in water, but completely dissolved on addition of a few drops of H Cl. In this solution phospho-molybdic acid produced a yellow precipitate of a colloid nature, platinum tetra-chloride a copious precipitate of a similar nature soluble in absolute alcohol.

Ammonia gave a voluminous white precipitate (shown afterwards to be the free body), soluble in absolute alcohol, which solution on evaporation yielded a transparent crystalline mass of microscopic needles and plates.

Here, then, was a body of a distinctly basic character, crystalline in structure, insoluble in water, but yielding a soluble hydrochlorate, and possessing further properties indicating its definite and homogeneous character.

Discovery of a new alkaloid, Psychosine.

Purification.—The whole available quantity was dissolved in water containing HCl, the solution filtered from some insoluble matter and phospho-molybdic acid in HNO_3 solution added in excess. The precipitate so obtained was, after trituration with water thrown on a filter, and after freeing from excess of HNO_3 decomposed by BaH_2O_2 in the usual

way, excess of $Ba H_2O_2$ being removed by means of $C O_2$. From the solid matter the new base was obtained by extraction with absolute alcohol, the alcoholic solution evaporated to dryness, and the residue so obtained placed over $H_2 SO_4$ in vacuo. After some days it admitted of pulverisation, and after drying finally at 100° the following preliminary analysis was made.

The formula deducible from this analysis is stated with all the reserve necessarily accompanying the determination of the formula of a body of very difficult properties and not yet sufficiently investigated.

Preliminary analysis:—Substance dried first in vacuo over $H_2 S O_4$, finally at 100°.

(*a*) 0·3114 grm. burned with lead chromate and copper (free from occluded hydrogen) gave 0·7064 grm. CO_2 and 0·2830 $H_2 O$ = 61·86 °/₀ and 10·09 °/₀ H.

(*b*) 0·0234 grm. gave by combustion in vacuo with cupric oxide and copper 0·54 c.c. nitrogen gas normal = 2·88 °/₀ N.

Computation of analyses.

Per-centage found.	÷ At. Wgts.	÷ N=1
C=61·86	5·155	25·1
H=10·09	10·097	49·2
N= 2·88	0·205	1·0
O=25·17	1·573	7·6

$= C_{25} H_{49} N O_8$.

To this body I have given the name of *Psychosine*.

Properties of Psychosine and its Hydrochlorate.

The free base.

1. Crystalline as deposited from its alcoholic solution.
2. Insoluble in water. The crystalline body when covered with water swells up but does not dissolve. Alkaline reaction.
3. Soluble in very dilute H Cl to a brilliantly clear solution, soluble in alcohol and in ether.
4. Soluble in dilute $H_2 S O_4$.
5. With $H_2 S O_4$ and sugar gives the *purple reaction* peculiar to the cerebrine and biliary bodies.
6. In its alcoholic solution $Ba H_2 O_2$ causes a gelatinous precipitate.
7. On heating on platinum foil burns easily with a luminous flame, swelling up and leaving much carbon.

The Hydrochlorate.

1. Soluble in water. The base is possibly diacidic, as its solution maintains an alkaline reaction in presence of a minimum of HCl necessary for its solution.
2. HNO_3 produces in the solution a transparent gelatinous precipitate soluble on further addition of water, again precipitated by further addition of HNO_3, and so on until HNO_3 ceases to give a further precipitate in the diluted solution.
3. The precipitate by HNO_3 is entirely soluble in ether.
4. Phospho-molybdic acid produces in the solution a copious yellow adhesive precipitate, becoming granular on trituration with large excess of the reagent. This precipitate is soluble in ether, with a brilliant yellow colour. It is necessary to avoid all excess of concentrated nitric acid in this reaction, as the base is easily nitrited and thereby changed in fundamental properties.

5. With platinum tetrachloride an amorphous yellow precipitate soluble in alcohol, precipitated from its alcoholic solution by ether, easily soluble in large excess of ether.
6. With $AuCl_3$ and HCl a yellow precipitate.
7. With $CdCl_2$ a white amorphous precipitate.
8. With picric acid a yellow amorphous precipitate; with tannic acid no precipitate; with ammonia a dense white precipitate (free body) soluble in alcohol, thence deposited crystalline.

The hydrochlorate further gave with KHO precipitate; NaHO precipitate; BaH_2O_2 dense precipitate; Na_2CO_3 pulverulent precipitate, probably carbonate; $HgCl_2$ in excess of KI, dense white precipitate with a solution of chloride of bismuth in excess of IK, a yellow precipitate, easily soluble in alcohol.

b. Second Series of Experiments.

In considering the broad results of the above first series of experiments, and by the light of Exp. II., it was determined to institute a new series of experiments, in order to fix the governing conditions under which the new base might be isolated, and at the same time to look for this body in various other preparations belonging to the cerebrine group. The six following experiments were undertaken, the last three being attended with success, psychosine being isolated in considerable quantity. A special tube was employed in the first five experiments. This was a strong brass tube closed at one end, 18 inches long and 1½ inch diameter, thickly lined with platinum, the open end being closed by means of a solid platinum cap and lever screw. The tube when charged was heated in the air-bath to the required temperature.

The following preparations were used:—In the first four experiments "prep. 1317," being first hour's deposit from second hour's cerebrine; in the fifth experiment "prep. 1315," being second hour's deposit from first hour's cerebrine; in Exp. VI., "prep. 1316," being third hour's deposit from first hour's cerebrine.

Experiments I.–III. Series II.—45 grms. "prep. 1317," 100 grms. BaH_2O_2, and sufficient water to form a paste, were heated in the platinum tube above described, for from 16 to 18 hours at 135°.

No psychosine was isolated in these experiments, all products being parallel to those of Exp. I. Series I.

Experiment IV. Series II.—45 grms. "prep. 1317," 100 grms. BaH_2O_2 and 100 c.c. water were heated in the platinum tube for three hours at 100°.

Much psychosine was obtained from the concentrated alcoholic mother liquors (*see* Exp. II. Series I.)

Experiment V. Series II.—45 grms. "prep. 1315," together with 100 grms. BaH_2O_2 and 100c.c. water, were heated in the platinum tube for 3½ hours at 100°

More psychosine was here isolated than in any previous experiment, the final alcoholic mother liquors yielding on evaporation a transparent highly crystalline almost colourless mass.

Experiment VI. Series II.—25 grms. of "prep. 1316," together with 50 grams. BaH_2O_2 and sufficient water, were boiled for five hours in a platinum dish, the loss of water by evaporation being from time to time replenished and the whole constantly stirred. Here also a not inconsiderable quantity of the new body was isolated.

In all these chemolyses an aqueous solution was obtained in which the presence of sugar was distinctly indicated. This product of decomposition, though present in such small quantity, is of great importance when considered in conjunction with the results obtained in those series of experiments in which H_2SO_4 was used as a chemolytic agent.

In those experiments psychosine and sugar were among the main products of decomposition. Further similarity of results becomes evident in comparing these methods of chemolysis, but it is for future research to establish their absolute parallelism. As regards the chemolyses with baryta, it is evident that at 100° in sealed tubes, or even by simple boiling in an open vessel, these cerebrine bodies yield as one product of decomposition a new base; but at 135° in sealed tubes no new base is isolated. The conclusion is obvious that this body is an intermediate product of decomposition, and is further decomposed on further heating. The particular products of its ultimate decomposition will be matter for future research.

It is likewise for further research to substantiate or annul the hypothesis that psychosine is a nucleus common to the molecules of cerebrine, phrenosine, and perhaps kerasine.

3.—Chemolysis of Cerebrine and Phrenosine by Sulphuric Acid.

Experiment I.—The preparation used in this experiment was analysed with the following results :—

(*a.*) 0·290 grm. substance gave 0·7200 grm. CO_2 and 0·296 grm. H_2O = to 67·710 °/₀ C and 11·344 °/₀ H.

(*b.*) 0·3500 grm. gave 9·4c.c. N normal = 3·359 °/₀ N.

Computation of analyses.

	Per-centages.	÷ At. Wgts.	÷ N = 1.	
C	= 67·710	5·642	23·6	× 2
H	= 11·344	11·344	47·4	× 2
N	= 3·359	·239	1·0	× 2
O	= 17·589	1·099	4·5	× 2

$= C_{48} H_{94} N_2 O_9$.

The body was therefore probably a mixture of one molecule of cerebrine with two molecules of phrenosine, very similar to the one described on p. 185 of Rep. 1874.

10 grms. of this preparation were boiled in 100 c.c. of water, containing 4·grms. H_2SO_4 during two hours. At first the whole mixture grew thick like starch paste; it next cleared and separated into a fluid and a granular white matter which was soft in the hot state. Where the dish became at all dry at the sides a purple colour appeared. The filtrate and solid matter were examined as under.

Examination of sulphuric acid solution.

The sulphuric acid was removed by baryta, and the excess of the latter by carbonic anhydride. The concentrated filtrate had a smell which reminded of hot sugar solutions. Portions were examined as follows :—

(1.) A little evaporated to dryness left a yellow residue which fused and burnt like sugar.

(2.) Not distinctly sweet to the taste.

(3.) Contained baryta in combination (sugars have this property).

(4.) With cerebrine and sulphuric acid it gave the purple reaction strongly and at once.

(5.) It reduced in a normal manner cupric sulphate as applied in Fehling's solution.
(6.) With iodine it gave a strongly brown colour.
(7.) Absolute alcohol precipitated it as a viscid mass which became hard on contact with fresh alcohol, the alcohol dissolved a small quantity.
(8.) On boiling with basic lead acetate the precipitate turned pink; acetate of lead and ammonia gave a precipitate which behaved similarly.

The substance was therefore probably sugar.

Examination of solid matter.

It was not examined at all in the state in which it was left by the sulphuric acid, but was boiled with baryta water for several hours. This gave a solution containing a mere vestige of a body having the characters of a base.

The baryum salts were dried and extracted with boiling nearly absolute alcohol. The extracts deposited a baryum salt of an organic acid, which was too small in quantity for further examination.

The alcoholic solution was evaporated to dryness on a water bath, and left a fluid yellowish mass which set on cooling into a soft solid. It had the properties of *psychosine*.

With hydrochloric acid and water it gave a starch-like solution, becoming clear on heating, and setting like jelly on cooling again. With more water a clear filterable solution was obtained which gave the following reactions:—

(1.) With nitric acid, a white curdy precipitate which was soluble in more water and nitric acid, and which was also soluble entirely in ether.
(2.) The nitric acid solution obtained in (1) gave a bulky and adhesive phospho-molybdic acid precipitate which was also entirely soluble in ether.
(3.) With platinic chloride it gave a bulky precipitate entirely soluble in alcohol.
(4.) No reducing action on alkaline cupric sulphate.

The Baryum Salts insoluble in alcohol were decomposed with hydrochloric acid in the presence of ether. This gave an ether solution containing a swollen matter in suspension; it was distilled to dryness, and after attempting several proceedings which were rendered futile by the insoluble matter alluded to, the residue was recrystallised from alcohol. The solution on cooling threw down a bulky white deposit; the mother liquor was discarded. The deposit was dried, and again recrystallised from watery alcohol. The final product fused about 70° C., and contained nitrogen, as proved by heating it with soda lime, when a volatile ammonium body was evolved in quantity and an oily body sublimed; this latter set on cooling but gave no ammonium salt.

The product gave a strong purple reaction with sulphuric acid and sugar.

It was now also insoluble in ether and only partially dissolved on the addition of hydrochloric acid; the part therefore which is soluble in ether must be a hydrochlorate.

It has not yet been analysed.

Experiment II.— In this experiment 21 grms. of a similar preparation to that used in Experiment I. were chemolysed in the platinum tube

previously described with 150c.c. water containing 3 grms. sulphuric acid (=2 °/₀ solution), at a temperature of 130—160° C. during three hours.

Examination of Sulphuric Acid Solution.

It was neutralised while hot by means of baryum carbonate, filtered and concentrated. The solution had all the characters of the corresponding solution obtained in Experiment I., and gave also the following tests:—

(1.) Would not crystallise.
(2.) Neutral to test paper.
(3.) Soluble in dilute alcohol; insoluble in absolute alcohol.
(4.) With ammoniacal nitrate of silver a reduction takes place on heating, and a silver mirror forms.
(5.) Produced a faint reduction of mercuric subnitrate.
(6.) Reduced a solution of trisnitrate of bismuth in sodic carbonate solution.
(7.) With pure glycocholic acid and sulphuric acid gave a brilliant Pettenkofers reaction.
(8.) With concentrated sulphuric acid, blackened.

The material which remained after the above re-actions had been made was freed from baryum in combination by means of careful precipitation with very dilute sulphuric acid. The solution was next concentrated, and then precipitated by absolute alcohol, dried at 95° C., and analysed 0·2784 grm. gave 0·3854 grm. $C\,O_2$ and 0·169 grm. $H_2\,O$, =37·75 °/₀ C, and 6·74 °/₀ H.

Computation of analyses.

Per-centages.	÷ At. Wgts.	÷ C=6.
C=37·75	3·146	6·
H= 6.74	6·74	12·6
O=55·51	3·469	6·6
	$=C_6\,H_{12}\,O_6$	

The carbon is rather low, as some difficulty was experienced in the burning. The analysis and reactions together, however, leave no doubt that the product was sugar. This was further confirmed by examining a solution of the body after decolorisation by charcoal, optically.

A solution containing, as determined by copper reduction method, 2·74 °/₀ of the sugar, was found to turn the plane of yellow sodium light 4° 24′ to the right at a temperature of 79° F. in a tube 200 m.m. long.

Examination of the Solid Product.

Washed and placed in ether, it chiefly dissolved, but left insoluble a gelatinous matter to be described further on.

The ether extract was distilled and the residue carefully examined for psychosine, but none was present.

After this it was recrystallised twice from 85 °/₀ alcohol, containing animal charcoal (which removed the colour), and the deposited matter was isolated and preserved for analysis. It was at this stage insoluble in ether, but soluble in the presence of HCl, and contained nitrogen; it fused at 70° C. The alcoholic mother liquor contained what seemed to be free fatty acid, soluble in ether. It furnished a baryum salt. *The gelatinous matter* was dissolved in hot absolute alcohol; it only deposited a trace of matter on cooling. The alcoholic solution was evaporated to

dryness on a water bath, and taken up in water and hydrochloric acid, in which it dissolved to a gelatinous paste which became quite clear when hot. This solution gave—

(1.) A bulky characteristic precipitate with phospho-molybdic acid.
(2.) A characteristic precipitate with watery platinic chloride ; this precipitate was soluble in alcohol.
(3.) A precipitate with ammonia.
(4.) A precipitate with picric acid.

The matter was therefore psychosine, but after these tests and others had been made, there was not left enough for analysis.

The products of the chemolysis of cerebrine and phrenosine, with sulphuric acid, are therefore sugar, psychosine, a body fusible at 70° C. and containing nitrogen (perhaps an amidated fatty acid), a fatty acid free from nitrogen and which gives a baryum salt. The gelatinous body which accompanied the amidated body in Experiment I., and rendered the ether solution unfilterable, is perhaps to be considered as identical in nature with that dissolved in the ether ; this is plausible because in the absence of hydrochloric acid both were insoluble in ether.

That body in Experiment II. which was at one time soluble in ether (as sulphate ?), also became ultimately insoluble in ether, and inasmuch as it had the same fusing point as the similar one in Experiment I. it may be considered as allied to it or identical with it.

It is probable that the small quantity of fatty acid which was obtained was derived from the amidated body by the chemolysis having proceeded further towards ultimate results. The chemolyses effected by baryta gave results similar to those described above ; while psychosine formed the most prominent product the evidence that sugar was formed was also indisputable. An insoluble in ether baryum salt was also obtained which with ether and hydrochloric acid behaved like similar preparations described in the sulphuric acid chemolyses ; and from the fact that this contained nitrogen, the free body may be regarded as identical with the one described above which fused at 70° C., and also contained nitrogen.

The fatty acid, whose baryum salt was obtained and found to be soluble in ether, was perhaps identical with the fatty acid which remained in small quantity in the alcoholic mother liquor of the recrystallised amidated substance obtained in Experiment II. with sulphuric acid.

It is therefore evident that the bodies of the cerebrine class show some analogy to the class of bodies known in chemistry as saccharides or glucosides, which are derived from one or several molecules of any sugar, by the substitution of one or several hydroxyls by one or several molecules of acid. Thus distearic glucoside, $C_{42}H_{78}O_7$ is produced according to the equation $C_6H_{12}O_6 + 2C_{18}H_{36}O_2 = C_{42}H_{78}O_7 + 3H_2O$. These glucosides yield the original substances from which they are derived by being boiled with dilute acids. But the cerebrines differ from the saccharides as yet extracted from natural products or obtained by chemical synthesis in this, that they contain nitrogen either in the form of amidated fatty acids, or of ammonium bases, or both. Moreover at least one of the fatty acids as yet met with in cerebrine seems to be peculiar and as yet unknown. The foregoing research has therefore had to contend with difficulties which are too well recognised in animal chemistry to require further discussion. But it has also furnished important data towards the elucidation of the question proposed, and fixed the direction in which inquiry will have to be continued.

* *Note on the purple reaction of the bodies of the cerebrine group and certain fatty acids with sulphuric acid and sugar.*

All the bodies of the cerebrine group, and certain decomposition products of kephaline, myeline, cerebrine, and phrenosine, give with strong sulphuric acid and sugar that colour reaction which as applied to biliary substances is known under the name of Pettenkofer's test.

Psychosine from cerebrine; the amidated fatty acid from cerebrine; the fatty acid from kephaline, which yields a baryum salt soluble in ether; and an acid from myeline—all these give the purple colour test.

Now cerebrine gives with sulphuric acid alone, and without the addition of sugar, this purple colour, but a longer time is required for its development than when sugar is also used.

The sulphuric acid may be supposed to act by splitting up the molecule of cerebrine into fatty acids (amidated or otherwise) on the one and a simple saccharide on the other hand, so that the addition of sugar at this stage at once developes the purple colour; but if sugar be not added, the sulphuric acid after more prolonged influence splits up the residue of the molecule of cerebrine, i.e. the simple saccharide, into a fatty radicle and sugar, and thus furnishes the essential ingredients for the purple reaction.

Ordinary mercantile palmitic acid fails to give it; on the other hand, mercantile stearic acid, and oleic acid from oil of almonds and from lecithine, do give the reaction.

III.—STUDY OF THE PRINCIPLES SOLUBLE IN WATER.

1.—Water Extracts of Oxbrains.

Experiment I.—The concentrated water extracts of brains employed in the following processes had a gravity of 17° B=1·13 sp. gr.

The solution was treated with baryta water to complete precipitation (*a*), the filtrate was completely precipitated with neutral acetate of lead (*b*), and the filtrate from this precipitate was completely precipitated by basic lead acetate (*c*). The mother-liquor was reserved (*d*).

(*a.*) *Examination of Baryta Precipitate.*—It was washed and dried, and found to contain 77·8 °/₀ ash. It was now divided into two halves, which were treated as described below.

Treatment of Baryta Precipitate with H Cl.—This gave a red solution and a precipitate chiefly consisting of $Ba\,SO_4$. This precipitate was digested in warm dilute caustic potash; the filtrate gave with H Cl an amorphous precipitate, so also with acetic acid. The whole was now treated with acetic acid and the precipitate redissolved in caustic potash, and re-precipitated by acetic acid; the product appeared to belong to the uric acid group, but was proved not to be uric acid itself.

Treatment of Baryta Precipitate with $Na_2\,CO_3$.—On digestion there was obtained a solution which contained matter precipitable by acetic acid, and of the same nature as that from the H Cl extract.

(*b.*) *Examination of the normal Lead Precipitate.*—Washed and found to give 67 °/₀ of residue on ignition of a portion. This residue consisted of lead, its oxide, and much chloride.

It was now suspended in water and decomposed by sulphuretted hydrogen. The filtrate was now precipitated by phospho-molybdic acid, and the precipitate washed first with water acidified with nitric acid, and then with 85 °/₀ alcohol. On decomposing the precipitate with baryta in the

inary way, there was obtained a solution which contained alkaloidal ter, as evidenced by the precipitates it gave with $HgCl_2$, $AuCl_3$, picric acid.

The mother liquor from the phospho-molybdic acid precipitate was passed through the baryta process, and the excess of baryta removed by CO_2; this gave a colourless filtrate which produced with I_2Cl_6 a yellowish white precipitate. The filtrate from this gave a ther precipitate on boiling. They were united dissolved in ammonia, iron removed by NH_4HS, and the filtrate concentrated, when it crystallised.

(*c.*) *Examination of the Basic Lead Precipitate.*—Washed, then decomposed by H_2S in water. The filtrate was concentrated and a small amount of alcohol added, which caused a large crop of crystals to be deposited on cooling; a further quantity was obtained from the mother liquor on continued concentration. These crystals were of pure inosite; they were sweet to the taste and were further identified.

The alcoholic mother liquor from the last crop of inosite proved to contain alkaloidal matter precipitable by $HgCl_2$. It was extracted by means of the phospho-molybdic acid process.

(*d.*) *Examination of Mother-liquor.* This was concentrated to a syrup and was tested for urea, the presence of which in any quantity above a trace was disproved. The solution was now divided into halves, which were separately examined.

(*a.*) Was precipitated to completion by $HgCl_2$, and the precipitate after washing decomposed by SH_2; on concentration of the filtrate in vacuo over sulphuric acid, crystals were obtained (=Alkaloid No. I.). The mother-liquor gave with absolute alcohol a copious precipitate, which appeared on further examination to consist of a second alkaloid in combination as hydrochlorate; in the presence of free acid it was soluble in alcohol.

Alkaloid No. I. as hydrochlorate in solution gave the following reactions:—

(1.) With $AuCl_3$ a bulky yellow precipitate.
(2.) With $PtCl_4$ no precipitate; addition of alcohol produced one on standing.
(3.) I in KI, bulky adhesive precipitate.
(4.) $HgCl_2$ in KI, precipitate.
(5.) Picric acid, a precipitate.

It was observed that evaporation of the alkaloid in presence of HCl to dryness gave a residue which when redissolved in water gave a bulky precipitate with $PtCl_4$.

The free base in water obtained by decomposition of the hydrochlorate with MgO gave in that state no $PtCl_4$ precipitate, but was precipitated by $HgCl_2$. The crystallised base was recognised as *hypoxanthine*.

(*b.*) The other half was freed from lead and baryta by sulphuric acid and the resulting solution again concentrated, after which it was freed from lactic acid as far as possible by extraction with large and repeated volumes of ether; from the watery solution the alkaloids were now obtained by application of the phospho-molybdic acid process. These were transformed into hydrochlorate, and on concentration a crop of crystals were obtained (Hypoxanthine + H Cl). The substances obtained, therefore, in this experiment were:—

(1.) A matter resembling but not identical with uric acid.
(2.) A crystallisable acid giving a ferric salt.
(3.) Inosite.
(4.) Hypoxanthine and another base.
(5.) Lactic acid.

Experiment II.—In this experiment the solution was perfectly extracted by ether (*a*) in the presence of sulphuric acid, an operation which extended over some months. Meanwhile crystals (*b*) formed gradually in the solution; these were separated from time to time and collected. Ultimately the watery solution was passed through the phospho-molybdic acid process (*c*), the mother liquor resulting from this precipitation being reserved (*d*).

(*a.*) *Examination of Ether Extracts.*—These were distilled till free from ether, and the resulting yellow solution, which was strongly acid, was boiled with oxide and carbonate of zinc, filtered and evaporated. In this way a considerable quantity of zinc salt has been accumulated and awaits further investigation; it is probably lactate of zinc.

(*b.*) *Examination of Crystalline deposit.* — These crystals were washed with water and dissolved in caustic potash, then reprecipitated in a crystalline form by sulphuric acid, subsequently they were recrystallised several times from water. They had the following characters:—

(1.) Difficultly soluble in water.
(2.) Free from sulphuric and hydrochloric acids.
(3.) On ignition decrepitate, blacken, scintillate, and leave a fusible residue which is dissipated in white fumes on further heating.
(4.) From a solution of the crystals in potash dilute sulphuric acid precipitated a highly crystalline substance.
(5.) Alcohol also produces a precipitate in the potash solution.

A watery solution gave the following tests:—

(6.) With $Pt\,Cl_4$ no precipitate, but a bulky one on the addition of alcohol.
(7.) $Ca\,Cl_2 + N\,H_3$ gave a copious precipitate, readily soluble in nitric acid.
(8.) $Ba\,H_2\,O_2$ a copious precipitate, soluble in $H\,N\,O_3$.
(9.) $Mg\,S\,O_4 + N\,H_4\,H\,O$, precipitate.
(10.) $Fe_2\,Cl_6$ no precipitate.
(11.) $Pb\,(C_2\,H_3\,O_2)_2$ a copious precipitate insoluble in water at 100°, soluble in nitric acid.

The whole quantity was now dissolved in water, precipitated by lead acetate and decomposed by $S\,H_2$; the concentrated filtrate had an acid reaction and crystallised on cooling; a portion of the product was dissolved in water, neutralised by $Na\,H\,O$, and the solution tested gave—

(12.) A good silver salt with $Ag\,N\,O_3$, soluble in $H\,N\,O_3$.
(13.) Did not prevent the precipitation of $Fe_2\,Cl_6$ by $N\,H_4\,H\,O$.
(14.) Gave no precipitate with $K_2\,S\,O_4$ on stirring.

These tests exclude tartaric acid, while the exact nature of the acid has yet to be determined.

(*c.*) *Examination of Phospho-molybdic Acid precipitate.* — The solution resulting from the decomposition of this precipitate by baryta and freed from excess of baryum by $C\,O_2$, was treated with excess of oxide of silver. After several hours digestion in the cold, filtered and precipitated by $Ag\,N\,O_3$. The precipitate so obtained was decomposed by $S\,H_2$ and the resulting solution, which was strongly acid, gave the following reactions:—

(1.) With $Ag\,N\,O_3$ a precipitate which was greatly increased in amount by neutralising the solution.
(2.) This silver salt was entirely soluble in excess of $N\,H_3$ or $H\,N\,O_3$

The silver oxide precipitate was also decomposed by $S H_2$, and the ution thus obtained was found to contain some of the same matter as t t whose properties have just been described.

(*d.*) *Examination of Mother-liquor after Phospho-molybdic acid recipitate.*—This was completely precipitated by $Ba H_2 O_2$ in the hot d the filtrate freed from excess of baryum by $C O_2$. The filtrate s allowed to cool and then completely precipitated by $Hg Cl_2$; er precipitation with $Hg Cl_2$ the filtrate was reserved (*e*); the pre- itate after washing with water was decomposed by $H_2 S$. This gave a ck-red solution of a broth-like odour; this was treated with excess Ag_2O when $N H_3$ was evolved. After two or three hours digestion $N O_3$ was added to cause the precipitation of Ag Cl that might erwise have been dissolved by the $N H_3$; filtered and filtrate kept. extraction of the silver precipitate with dilute $H N O_3$ in the hot ich dissolved, and was deposited on cooling in white silky masses of poxanthine silver nitrate salt, which was purified by decomposition th $H_2 S$, thus giving free hypoxanthine nitrate.

The filtrate from the Ag_2O precipitate was rendered ammoniacal and rate of silver added; this gave no precipitate until the addition of $N O_3$, which caused a deposit; this deposit was soluble in boiling ter, and the solution had the following characters :—

(1.) With $Ag N O_3$ a feeble precipitate.

(2.) With ammoniacal nitrate of silver a bulky precipitate soluble in excess of ammonia or nitric acid.

(*e.*) *Treatment of Mother liquor from $Hg Cl_2$ precipitate.*—This was ncentrated and completely precipitated by basic acetate of lead, which ecipitate on decomposition with $S H_2$ gave a solution which yielded osite on evaporation, and a mother liquor from which strong alcohol parated an oily precipitate which crystallised on cooling, and which as regarded as a derivative of inosite.

The following bodies, therefore, represent the results of the regoing study :—

Hypoxanthine, and a second base.
New crystallisable acid giving no insoluble iron salt.
Lactic acid.
Inosite, and what is perhaps a product of change of inosite.

Experiment III. — A quantity was passed through the phospho- olybdic acid process, and the product was treated with excess of ide of silver filtered and washed.

Treatment of Precipitate.—Decomposed by $S H_2$, filtered, and the lphide of silver extracted with much boiling water, the filtrate and ater extracts were united and evaporated to dryness, and thus fur- shed a residue of hypoxanthine with some little foreign matter; the ypoxanthine was purified by dissolving in a little $H N O_3$, decolorising ith charcoal, and re-precipitation with $N H_3$.

Treatment of the Filtrate.—This was rendered ammoniacal and preci- tated by ammonio-silver nitrate, washed with water containing a little mmonia, then decomposed by $S H_2$; the yellow filtrate made a deposit concentration and gave a yellow mother-liquor.

Examination of Deposit.—This was dissolved in boiling water, and as re-precipitated on cooling. It had the following characters :—

(1.) Its aqueous solution gave with $Ag N O_3$ a white gelatinous precipitate insoluble in excess of ammonia, but entirely soluble in much water and nitric acid, from which solution it deposited on cooling in a perfectly white form.

These tests would seem to indicate that the body under examination was hypoxanthine, although the two next tests appear to exclude both hypoxanthine and xanthine.

(2.) Warmed with HNO_3 and gently dried it left a yellow residue which did not change colour on heating, but burnt and evolved cyanogen, leaving a charcoal.

(3.) The yellow body failed to give the purple coloration with KHO.

In all probability, therefore, this body was a new member of the xanthine series.

On examination of Yellow Mother-liquor, it was found to contain hypoxanthine as characterised by its silver nitrate compound, &c.

In this investigation, therefore, besides hypoxanthine, a substance of very similar properties, and apparently identical with a similar body existing in diabetic urine, was found.

General note regarding the isolation and separation of the Alkaloids contained in Ox Brain.

The presence of the alkaloids in the water extracts of brain matter is indicated by the precipitates which they give with $Au\ Cl_3$, I in KI, $Hg\ Cl_2$ in KI, picric, tannic, and phospho-molybdic acids.

They may be obtained as shown in the preceding pages by the application of the phospho-molybdic acid process, $Hg\ Cl_2$ process, and collaterally by the basic lead acetate process (for inosite). The latter process, however, does not yield them if preceded by the phospho-molybdic acid process. They may be separated when in the free state by evaporation to a syrupy consistency when the hypoxanthine is deposited while the second base is uncrystallisable. The same remarks apply to a mixture of the hydrochlorates, the hypoxanthine compound in this case being obtained in a crystalline form. Neither the watery solution of the free hypoxanthine nor of its hydrochlorate gives a $Pt\ Cl_4$ precipitate. The hypoxanthine may be purified by dissolving in boiling water and addition of excess of silver nitrate and nitric acid. The precipitate so formed gradually dissolves in hot nitric acid, and from the filtered solution deposits on cooling in a mass of homogeneous needles. Obtained in this way it is pure, as testified by the following analysis :—

(*a.*) 0·5628 grm. gave 0·255 grm. Ag Cl = 34·100 % Ag.

(*b.*) 0·4834 grm. gave 0·350 grm. CO_2 and 0·067 grm. H_2O = 19·746 % C and 1·539 % H.

(*c.*) 0·4756 grm. gave 89·46c.c. nitrogen normal = 23·516 % nitrogen.

Computation of analyses :—

Per-centages found.	÷ At. Wgts.	÷ Ag = 1.
C = 19·746	1·645	5·2
H = 1·539	1·539	4·8
N = 23·516	1·679	5·3
O = 21·099	1·318	4·1
Ag = 34·100	0·315	1·0

$$= C_5 H_4 N_4 O + Ag N O_3.$$

A combination of the hypoxanthine with silver was also obtained by precipitation of its solution with ammoniacal silver nitrate; it contained 60·46 % silver, whereas had it been pure $C_5 H_4 N_4 O Ag_2$ it should have contained 61·7 %.

The hydrochlorate of the second base is soluble in alcohol but precipitated by ether; on the whole it is a perishable compound. In one

experiment where the hypoxanthine had been removed from a mixture of the two bodies, this second base was again passed through the phospho-molybdic process, the product gave a precipitate with $Ag\ N\ O_3$ in the presence of $H\ N\ O_3$, which proved to be a further quantity of hypoxanthine salt. Thus purified the second base was again passed through the phospho-molybdic acid process, then converted into gold chloride salt and analysed.

(*a.*) 0·5944 grm. gave 0·1894 grm. gold=31·864 °/₀ gold.
(*b.*) 0·530 grm. gave 0·243 grm. Ag Cl=11·34 °/₀ chlorine.
(*c.*) 0·5570 grm. gave 0·559 grm. CO_2 and 0·187 grm. H_2O = 27·37 °/₀ C and 3·71 °/₀ H.
(*d.*) 0·3612 grm. gave 34·3c.c. nitrogen normal = 11·88 °/₀ N.

Computation of analyses.—In this compound the gold stands to the chlorine as 1:2; deducting now the gold and chlorine and recalculating the per-centages, we have :—

	÷ At. Wgts.	÷ N = 1.
C = 48·18	4·015	2·7
H = 6·53	6·530	4·3
N = 20·92	1·494	1·0
O = 24·37	1·523	1·0
	= $C_3\ H_4\ N\ O$.	

2.—Water Extracts of Human Brains.

The water extracts were precipitated with excess of gold chloride, and the precipitate thus obtained was decomposed by hydrothion. On concentration of the resulting filtrate a crop of crystals was deposited. These crystals proved to consist of *hypoxanthine*, and its silver nitrate compound was prepared, re-crystallised from water strongly acidulated with $H\ N\ O_3$, and identified.

The mother liquor after the above crystals were separated was passed through the phospho-molybdic acid process and the excess of baryum removed by $C\ O_2$. From the solution the gold salt was reconstructed, and an attempt was made to obtain it as hydrochlorate in a crystalline form, but concentration was fatal to the project.

The mother liquor of the Au Cl_3 precipitate was freed from excess of gold by $S\ H_2$ and extracted during a long period with large volumes of ether. These ether extracts on distillation left a residue which furnished a crystalline zinc salt and a mother liquor, the bodies being probably identical with those prepared in a similar way from ox brain water extract (lactate of zinc and glycerin ?).

Continued extraction with ether gave rise to the formation in the solutions of crystals which were probably of the same nature as those described in the case of ox brains.

The mother liquors which remained after the Au Cl_3 and ether treatment were freed from sulphuric and phosphoric acids, and while alkaline precipitated by basic lead acetate. This precipitate was washed and decomposed by $S\ H_2$. Inosite was not sought for on account of the presence of much hydro-chloric acid introduced by the gold process. It was therefore neutralised by Mg O, and the concentrated liquid precipitated by alcohol.

Examination of this precipitate.—It was redissolved in water and re-precipitated by alcohol several times, by which means the excess of

$Mg\ Cl_2$ was removed in the mother liquors. The matter was then once more dissolved in water and precipitated while boiling with boiling solution of $Fe_2\ Cl_6$. This was done because the precipitate was only constant under these conditions, and was soluble in excess either of the solution or of the precipitate. The gelatinous precipitate, which became sandy on heating, was isolated, washed, dissolved in $N\ H_3$, and the iron removed by means of $S\ H_2$. The filtrate failed to crystallise on concentration. It gave the following reactions :—

(1.) Red in colour, acid to test paper.
(2.) With cupric acetate, slight greenish precipitate.
(3.) With $Fe_2\ Cl_6$, greenish brown precipitate soluble in excess.
(4.) $Hg\ Cl_2$, white precipitate.
(5.) $Cd\ Cl_2$ in alcohol, viscid precipitate soluble in water.
(6.) $Pb\ (C\ H_3\ O_2)_2$, thick white precipitate.
(7.) $Ag\ N\ O_3$, precipitate soluble in $H\ N\ O_3$ in the warm, and soluble in $N\ H_3$; decomposed on heating gently, becoming first of a carmine colour, then black.

The whole was now converted into silver salt, which blackened somewhat during washing and preparation for analysis. Dried at 100°.

(*a.*) 0·377 grm. gave 0·281 grm. $Ag = 74·53\%\ Ag$.

(*b.*) 1·1312 grm. gave 0·3774 grm. $C\ O_2$ and 0·120 grm. $H_2\ O =$ 1·178 % H and 9·105 % C.

Computation of analyses :—

Per-centages found.	÷ At. Wgts.	÷ Ag. = 1.
C = 9·105	0·758	1·09
H = 1·178	1·178	1·70
Ag=74·535	0·690	1·0
O =15·182	0·948	1·3

$$= \times 3 = C_3\ H_5\ Ag_3\ O_4.$$

74·535 % Ag leads to an atomic weight for the organic matter when multiplied by 3 of 108; $C_3\ H_8\ O_4 = 108$. This salt therefore is the fully saturated silver salt of a tribasic acid isomeric with glyceric.

The products then obtained in this study were—
Hypoxanthine.
A second base not analysed.
Lactic acid.
New tribasic acid.
Perhaps glycerine.

IV.—ANALYTICAL TECHNICAL INQUIRIES.

1.—Note on the Specific Gravity of Human and Bovine Brains, and their White and Grey Matter, and on the Determination of the Relative Amounts of White and Grey Matter.

The present statement is a preliminary notice of some experiments which have led to the solution of an anatomical problem hitherto believed to be unattainable, and to some remarkable pathological data.

The specific gravity of the white and grey matter differs within limits, which are much wider in disease than in health ; but in all cases grey

matter is of a lesser specific gravity, or more watery, than white matter, which is denser, or less watery.

Given the weight in air of an entire brain, and given the specific gravity of the entire brain, and given the specific gravities of the grey and the white matter respectively of the same brain, a simple calculation must lead us to the quantities of white and grey matter composing this brain.

It was easy enough to determine the specific gravities of portions of grey and white matter. But the determination of the specific gravity of an entire human brain required the construction of a new apparatus. This has just been completed, and will be employed as materials may be obtained.

I hope that this method of inquiry may help to throw light on brain diseases which are commonly the causes of various forms of madness. In a case of sclerosis the density of the white matter was actually found increased, as the anatomical term implies, its specific gravity being 1049. *But the grey matter was not only not higher in its specific gravity, but was actually below the normal specific gravity commonly assigned to grey matter* in physiological text books, namely as low as 1028.

A few determinations of the specific gravity of some entire ox brains led to 1034 and 1035 as average resultants.

2.—Note of an Essay on Combustion in Vacuo.

This paper was read before the Chemical Society, and published in their Journal (Vol. 2, 1876,) under the title "*Note of some Trials of Frankland and Armstrong's Combustion Process.*" *By J. L. W. Thudichum and C. T. Kingzett.* The authors show that this process is applicable to investigations in physiological chemistry, where the quantities of matter at the command of the investigator are often so small as not to admit of complete analyses by the ordinary methods.

In this method of analysis the determination of the nitrogen and carbon in organic substances, and of the relation of the one element to the other, can be conducted on a few centigrams of material, if the oxide of copper which is employed be free from occluded carbon. For this purpose it must be prepared as directed by Frankland and Armstrong, or must, as shown by the authors of the present essay, be heated to bright red heat in vacuo before use. But even should this not be done, and oxide of copper as ordinarily employed be used, the nitrogen determination is thoroughly trustworthy. Further, this method is available for determination of the nitrogen contained in all ammonium salts; thus, in the case of nitrate of ammonium both the nitrogen of the nitric acid and of the ammonium is set free, and the amount obtained exactly corresponds with that required by theory.

3.—Note of an Essay on the Determination of Hydrogen occluded by Copper.

This paper was read before the Chemical Society, and published in their Journal (Vol. 2, 1876,) under the title "*On the Determination of Hydrogen occluded by Copper, with special reference to Organic Analyses.*" *By J. L. W. Thudichum and Henry W. Hake.*

It had been advanced that an error of excess in hydrogen determinations (in combustion of organic bodies with cupric oxide and metallic copper) was introduced by the use of the metallic copper, which substance, after the usual preparatory process of oxidation at a red heat in air and subsequent reduction at a red heat and cooling in an atmosphere of hydrogen, occluded a considerable quantity of this gas; that indeed a

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On the Chemical Constitution of the Brain, by Dr. Thudichum.

source of error existed in material used for the purpose of ensuring the utmost accuracy. To avoid the error the use of silver wire gauze had even been recommended. An examination of previous quantitative experiments made with regard to the occlusion of hydrogen by copper by Melsens, Graham, and Johnson, showed that the results arrived at had no concatenation whatever, a fact only to be explained by the varying conditions under which the respective experiments were made.

Experiments were therefore instituted in the Pathological Laboratory to determine the extent and conditions of occlusion of hydrogen by the ordinary copper wire gauze used in combustions. The amount occluded in each experiment was determined by exhausting at a red heat a tube containing the wire gauze rolls, after these had been subjected to the above-mentioned oxidation and reduction and cooling in hydrogen, and the gas so obtained collected over mercury and measured.

The results arrived at are of analytical importance, and are as follows :—

(1.) That the amount of hydrogen occluded by copper wire gauze which has undergone the usual process of oxidation and reduction *more than once*, is so small as to cause the inappreciable error of about 0·0039 per cent. excess of hydrogen, on the assumption that 0·4 grm. substance is employed for analysis.

(2.) That the amount occluded by copper wire gauze which has not been previously subjected to this process is also extremely small, and might also, except in the most accurate determinations, be disregarded, causing an error only of about 0·025 per cent. excess of hydrogen.

(3.) That all possible error due to occlusion of hydrogen by copper wire gauze may be entirely avoided by a very simple expedient, viz., by allowing the copper after reduction at a red heat in an atmosphere of hydrogen to cool in an atmosphere of carbonic anhydride.

It gives me great pleasure to record the ability, skill, and assiduity with which, in the course of these inquiries, I have been aided by my assistants, Messrs. C. T. Kingzett and H. W. Hake, Ph.D.

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